

UTILITY
PATENT APPLICATION
TRANSMITTAL

Attorney Docket No. PICO

First Inventor or Application Identifier JEWELL, Jack L.

Title CONDUCTIVE ELEMENT WITH LATERAL OXIDATION...

Express Mail Label No.

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. ☒ * Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☒ Specification [Total Pages **36**]
(preferred arrangement set forth below)
- Descriptive title of the invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the invention
 - Brief Summary of the invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
- ☐ Drawing(s) (35 U.S.C. 113) [Total Sheets **7**]

Oath or Declaration [Total Page ☐]

- a. ☐ Newly executed (original or copy)
- b. ☒ Copy from a prior application (37 C.F.R. § 1.63(d))
(for continuation/divisional with Box 17 completed)
[Note Box 5 below]
- i. ☐ DELETION OF INVENTOR(S)

Signed statement attached deleting
inventor(s) named in the prior application,
see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

- ☐ Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a
copy of the oath or declaration is supplied under Box 4b, is
considered to be part of the disclosure of the accompanying
application and is hereby incorporated by reference therein.

6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
- a. ☐ Computer Readable Copy
- b. ☐ Paper Copy (identical to computer copy)
- c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ☐ Assignment Papers (cover sheet & document(s))
9. ☐ 37 C.F.R. §3.73(b) Statement
(when there is an assignee) ☒ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☒ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
14. ☒ * Small Entity Statement(s) ☐ Statement filed in prior application,
(PTO/SB/09-12) Status still proper and desired
15. ☐ Certified Copy of Priority Document(s)
(if foreign priority is claimed)
16. ☒ Other Associate Power of Attorney, EDC form and
Notice of Interference

* NOTE FOR ITEMS 1 & 14: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY
FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT
IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:

☐ Continuation ☒ Divisional ☐ Continuation-in-part (CIP) of prior application No: 09 / 457 303

Prior application information: Examiner KANG, Ellen Group / Art Unit 2501

18. CORRESPONDENCE ADDRESS

Customer Number or Bar Code Label



(Insert Customer Number or bar code label here)

or Correspondence address below

Name Jagtiani & Associates

PATENT TRADEMARK OFFICE

Address 10379-B Democracy Lane

City Fairfax

State Virginia

Zip Code 22030

Country United States of America

Telephone (703) 591-2664

Fax (703) 591-5907

Name (Print/Type) Ajay A. Jagtiani

Registration No. (Attorney/Agent) 35,205

Signature

Date April 20, 2000

12-17-1995 1:08PM

FROM JAGTIANI AND ASSOC 703 803 9387

P. 2

SMALL BUSINESS

| | | | |
|--------------------------|---|-----------|-----------|
| Applicant or Patentee: | JEWELL, Jack L. | Docket #: | PICO-0002 |
| Serial or Patent Number: | | Examiner: | |
| Filed or Issued: | December 17, 1995 | Art Unit: | |
| For: | CONDUCTIVE ELEMENT WITH LATERAL OXIDATION BARRIER | | |

**VERIFIED STATEMENT (DECLARATION) BY A SMALL BUSINESS CONCERN
CLAIMING SMALL ENTITY STATUS UNDER 37 C.F.R. §§ 1.9(f) AND 1.27(c)**

I hereby declare that I am

- ☒ the owner of the small business concern identified below;
- ☐ an official of the small business concern empowered to act on behalf of the concern identified below:

Name of Concern: **PicoLight, Incorporated**
Address: **4622 Sunshine Canyon Drive, Boulder, Colorado 80302**

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the matter described in:

- ☒ The specification filed herewith, with the title as listed above.
- ☐ The patent application identified above.
- ☐ The PCT International patent application identified above.
- ☐ The patent number identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention must file separate verified statements averring to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern who would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e). Each person or organization having any rights in the invention is listed below:

- ☒ No such person, concern or organization.
- ☐ Each such person, concern or organization as listed below:


| | |
|-----------|---|
| Full Name | <input type="checkbox"/> Individual <input type="checkbox"/> Small Business Concern <input type="checkbox"/> Nonprofit Organization |
| Address | |

| | |
|-----------|---|
| Full Name | <input type="checkbox"/> Individual <input type="checkbox"/> Small Business Concern <input type="checkbox"/> Nonprofit Organization |
| Address | |

☐ See attached sheet for additional person(s), concern(s) or organization(s).

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which the verified statement is directed.

| | |
|---|--|
| Name and Title | Date |
| Jack L. Jewell, President | December 17, 1995 |
| Address | Signature |
| 4622 Sunshine Canyon Drive Boulder, Colorado 80302 |  |

Inventor Information

Inventor One Given Name :: Jack L.
Family Name :: Jewell
Name Suffix :: Mr.
Postal Address Line One :: 4622 Sunshine Canyon Drive
Postal Address Line Two ::
City :: Boulder
State/Province :: Colorado
Country :: USA
Postal or Zip Code :: 80302
City of Residence :: Boulder
State/Prov. of Residence :: Colorado
Country of Residence :: USA
Citizenship :: USA

Correspondence Information

Correspondence Customer Number ::
Name Line One :: Ajay A. Jagtiani
Name Line Two :: Jagtiani & Associates
Address Line One :: Democracy Square Business Center
Address Line Two :: 10379-B Democracy Lane
City :: Fairfax
State/Province :: VA
Country ::
Postal or Zip Code :: 22030
Telephone :: (703) 591-2664
Fax :: (703) 591-5907
E-Mail :: IPLaw@Jagtiani.com

Application Information

Title Line One :: CONDUCTIVE ELEMENT WITH LATERAL
Title Line Two :: OXIDATION BARRIER

Total Drawing Sheets :: 7
Formal Drawings :: Y
Application Type :: Utility
Docket Number :: PICO-0029-1
Licensed - U S Government Agency ::
Contract Number ::
Grant Number ::
Secrecy Order in Parent Application ::

Representative Information

Representative Customer Number ::

Registration Number One :: 35,205

Registration Number Two :: 33,057

This application is a :: Divisional

> Application One :: 09/457,303

Filing Date :: December 9, 1999

Patent Number ::

which is a :: Divisional

>> Application Two :: 09/235,639

Filing Date :: January 22, 1999

Patent Number ::

which is a :: Divisional

>> Application Three :: 08/986,401

Filing Date :: December 8, 1997

Patent Number :: 5,903,589

which is a :: Divisional

> Application Four :: 08/964,598

Filing Date :: November 15, 1997

Patent Number :: 5,897,329

which is a :: Divisional

> Application Five :: 08/574,165

Filing Date :: December 18, 1995

Patent Number :: 5,719,891

Prior Foreign Applications

Foreign Application One ::

Filing Date ::

Country ::

Priority Claimed ::

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:)
)
JEWELL, Jack L.)
)
Serial Number: To be assigned) Art Unit: 2501
)
Filed: Concurrently herewith) Examiner: Kang, E.
)
For: CONDUCTIVE ELEMENT WITH LATERAL)
OXIDATION BARRIER)

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Prior to an examination on the merits, please amend the above-captioned application as follows:

IN THE SPECIFICATION

Please amend the Specification, without prejudice or disclaimer, as indicated below:

Page 11, lines 7 and 8, please replace the phrase "12 is assessed by pit 58" with -- 12 is accessed by pit 58 and oxidized via pit 58.--;

Page 14, lines 16 through 17, please replace the phrase "oxidizing layers 150 and nonoxidizing layers 152," with --oxidizing layers 24 and nonoxidizing layers 26,--; and

Page 16, line 3, please replace the phrase "through oxidizing layers 24." with -- through oxidizing layers 24, via holes or basins 174.--.

IN THE CLAIMS

Please cancel claims 1 through 56, without prejudice or disclaimer. Please add the claims as indicated below:

Serial Number: To be assigned

-- 57. A laser structure, comprising:

an active region;

a first electrical contact disposed on a first surface of said laser structure;

a second electrical contact, said active region being disposed between said first and second electrical contacts;

a first current blocking layer, said first current blocking layer being subject to physical change when exposed to a preselected agent;

first means for selectively exposing a portion of said first current blocking layer to said preselected agent to define a first unchanged region of said first current blocking layer surrounded by a first changed region of said first current blocking layer, said first unchanged region of said first current blocking layer being aligned with a preselected region of said active region, said first changed region being electrically insulative, said first unchanged region being electrically conductive;

wherein said first means for selectively exposing includes at least one etched depression extending from said first surface of said laser structure into the body of said laser structure and through said first current blocking layer to expose a portion of said current blocking layer to said preselected agent during manufacture of said laser structure.

58. The laser structure of claim 57, wherein: said laser structure is a vertical cavity surface emitting laser.

Serial Number: To be assigned

59. The laser structure of claim 57, further comprising:

a second current blocking layer, said second current blocking layer being subject to change when exposed to said preselected agent;

means for selectively exposing a portion of said second current blocking layer to said preselected agent to define a second unchanged region of said second current blocking layer surrounded by a second changed region of said second current blocking layer, said second unchanged region of said second current blocking layer being aligned with said preselected region of said active region, said second changed region being electrically insulative, said second unchanged region being electrically conductive, said first and second unchanged regions being aligned with each other to define a current channel extending through said preselected region of said active region; and

said means for selectively exposing a portion of said second current blocking layer further comprises at least one etched depression extending from said first surface of said laser into the body of said laser structure and through said second current blocking layer to expose a portion of said second current blocking layer to said preselected agent during manufacture of said laser structure.

60. The laser structure of claim 57, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first current blocking layer being exposed at a surface of said lasing

Serial Number: To be assigned

portion.

61. The laser structure of claim 59, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said lasing portion.

62. The laser structure of claim 57, wherein: said preselected agent is an oxidizing agent and said physical change is oxidation.

63. The laser structure of claim 62, wherein: said oxidizing agent is water vapor.

64. The laser structure of claim 57, wherein: said preselected agent is an etchant.

65. The laser structure of claim 64, wherein: said etchant is an acid.

66. The laser structure of claim 57, wherein said first means for selectively exposing further comprises: four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first current blocking layer to expose a plurality of portions of said current blocking layer to said preselected

Serial Number: To be assigned

agent during manufacture of said laser structure.

67. The laser structure of claim 57, further comprising:

an first mirror structure comprising a first plurality of layers;

a second mirror structure comprising a second plurality of layers, said active region being disposed between said first and second mirror structures.

68. The laser structure of claim 59, wherein: said means for selectively exposing a portion of said second current blocking layer further comprises four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said second current blocking layer to expose a plurality of portions of said second current blocking layer to said preselected agent during manufacture of said laser structure.

69. A laser structure, comprising:

an active region;

a first electrical contact disposed on a first surface of said laser structure;

a second electrical contact, said active region being disposed between said first and second electrical contacts, said laser structure being a vertical cavity surface emitting laser;

a first current blocking layer, said first current blocking layer being subject to oxidation when exposed to an oxidizing agent;

Serial Number: To be assigned

a second current blocking layer, said second current blocking layer being subject to oxidation when exposed to said oxidizing agent;

a first means for selectively exposing a portion of said first current blocking layer to said oxidizing agent to define a first nonoxidized region of said first current blocking layer surrounded by a first oxidized region of said first current blocking layer, said first nonoxidized region of said first current blocking layer being aligned with a preselected region of said active region, said first oxidized region being electrically insulative, said first nonoxidized region being electrically conductive;

second means for selectively exposing a portion of said second current blocking layer to said oxidizing agent to define a second nonoxidized region of said second current blocking layer surrounded by a second oxidized region of said second current blocking layer, said second nonoxidizing region of said second current blocking layer being aligned with said preselected region of said active region, said second oxidized region being electrically insulative, said second nonoxidized region being electrically conductive, said first and second nonoxidized regions being aligned with each other to define a current channel extending through said preselected region of said active region; and

wherein said first means for selectively exposing and said second means for selectively exposing include at least one etched depression extending from said first surface of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a portion of said first and second current blocking layers to said preselected agent during manufacture of said laser structure.

Serial Number: To be assigned

70. The laser structure of claim 69, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said lasing portion.

71. The laser structure of claim 70, wherein: said first and second current blocking layers comprise an aluminum bearing material.

72. The laser structure of claim 70, wherein: said oxidizing agent is water vapor.

73. The laser structure of claim 69, wherein: said first and second means for selectively exposing further include four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a plurality of portions of said current blocking layers to said preselected agent during manufacture of said laser structure.

74. A laser structure, comprising:

an active region;

a first electrical contact disposed on a first surface of said laser structure;

Serial Number: To be assigned

a second electrical contact, said active region being disposed between said first and second electrical contacts, said laser structure being a vertical cavity surface emitting laser;

a first current blocking layer, said first current blocking layer being subject to oxidation when exposed to an oxidizing agent;

a second current blocking layer, said second current blocking layer being subject to oxidation when exposed to said oxidizing agent;

first means for selectively exposing a portion of said first current blocking layer to said oxidizing agent to define a first nonoxidized region of said first current blocking layer surrounded by a first oxidized region of said first current blocking layer, said first nonoxidized region of said first current blocking layer being aligned with a preselected region of said active region, said first oxidized region being electrically insulative, said first nonoxidized region being electrically conductive;

second means for selectively exposing a portion of said second current blocking layer to said oxidizing agent to define a second nonoxidized region of said second current blocking layer surrounded by a second oxidized region of said second current blocking layer, said second nonoxidized region of said second current blocking layer being aligned with said preselected region of said active region, said second oxidized region being electrically insulative, said second nonoxidized region being electrically conductive, said first and second nonoxidized regions being aligned with each other to define a current channel extending through said preselected region of said active region; and

Serial Number: To be assigned

wherein said first and second means for selectively exposing further comprise at least one etched depression extending from said first surfaces of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a portion of said current blocking layers to said preselected agent during manufacture of said laser structure.

75. The laser structure of claim 74, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said lasing portion, said first and second current blocking layers comprise an aluminum bearing material, said oxidizing agent being water vapor.

76. The laser structure of claim 74, further comprising:

a plurality of etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first current blocking layer to expose a plurality of portions of said current blocking layer to said oxidizing agent during manufacture of said laser structure.

77. The laser structure of claim 74, wherein: the first and second means for exposing further include four etched depressions extending from said first surface of said laser

Serial Number: To be assigned

structure into the body of said laser structure and through said first and second current blocking layers to expose a plurality of portions of said current blocking layers to said preselected agent during manufacture of said laser structure. --

Serial Number: To be assigned

REMARKS

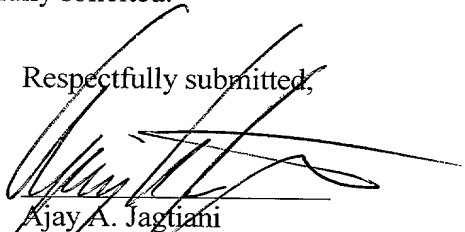
Favorable reconsideration of this application as presently amended is respectfully requested.

The Specification has been amended to clarify the oxidation step as provided in U.S. Patent 6,014,395 and other patents that this application claims as priority. No new matter has been entered by the amendment to the Specification.

The claims have been amended to be identical to U.S. Patent 5,903,588. An Interference is requested in the enclosed Notice of Interference. Basis for adding these claims may be found in the attached table.

In view of the foregoing, it is respectfully submitted that this application is now in condition for allowance, and favorable action is respectfully solicited.

Respectfully submitted,



Ajay A. Jagtiani
Reg. No. 65,205

JAGTIANI & ASSOCIATES
Democracy Square Business Center
10379-B Democracy Lane
Fairfax, Virginia 22030
(703) 591-2664

April 20, 2000

| Present Application PICO-0029-1 | Basis in Specification |
|--|---|
| Claim 57 | |
| A laser structure, comprising: an active region; | Column 7, lines 16, 24, 32,33, 48, and 57. See Figs. 5A-F (86). |
| a first electrical contact disposed on a first surface of said laser structure; | Column 7, lines 21, 29-30, 36, 44, 53, and 60. See Figs. 5A-F (96). |
| a second electrical contact, said active region being disposed between said first and second electrical contacts; | Column 7, lines 22, 30 and 36. See Figs. 5A-C (98). Column 7, lines 45, 53 and 60. See Figs. 5D-F (128). Figs. 5A-C illustrate active region 86 being disposed between top contact 96 and bottom contact 98. Figs. D-F illustrate active region 86 being disposed between top contact 96 and bottom contact 128. |
| a first current blocking layer, said first current blocking layer being subject to physical change when exposed to a preselected agent; | Column 6, lines 13-14, referring to Fig. 2B (illustrating oxidizing layer 12). See also Column 7, lines 28-34. See Figs. 5A-F (teaching oxidized portions 28). |
| first means for selectively exposing a portion of said first current blocking layer to said preselected agent to define a first unchanged region of said first current blocking layer surrounded by a first changed region of said first current blocking layer, said first unchanged region of said first current blocking layer being aligned with a preselected region of said active region, said first changed region being electrically insulative, said first unchanged region being electrically conductive; | Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region (nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the etching of the plurality of pits 58 and 58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a |

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| | <p>plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.</p> |
| <p>wherein said first means for selectively exposing includes at least one etched depression extending from said first surface of said laser structure into the body of said laser structure and through said first current blocking layer to expose a portion of said current blocking layer to said preselected agent during manufacture of said laser structure.</p> | <p>Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174.</p> |
| Claim 58 | |
| <p>The laser structure of claim 57, wherein: said laser structure is a vertical cavity surface emitting laser.</p> | <p>Column 6, lines 43. See Figs. 5A (80), 5B (102), 5C (110), 5D (116), 5E (130) and 5F (138). Fig. 6 illustrates an example of a processing method to produce VSCELs. See also Column 9, line 123; Fig. 7 (180).</p> |
| Claim 59 | |
| <p>The laser structure of claim 57, further comprising: a second current blocking layer, said second current blocking layer being subject to change when exposed to said preselected agent;</p> | <p>Column 9, lines 4-9. See Fig. 6G (175). See also column 5, lines 52-55, Fig. 1D (a plurality of oxidizing layers 12). Figs. 5A-F illustrate a plurality of current blocking layers 28, each being oxidized portions of the current blocking layer being subject to oxidation when exposed to an oxidizing agent.</p> |

means for selectively exposing a portion of said second current blocking layer to said preselected agent to define a second unchanged region of said second current blocking layer surrounded by a second changed region of said second current blocking layer, said second unchanged region of said second current blocking layer being aligned with said preselected region of said active region, said second changed region being electrically insulative, said second unchanged region being electrically conductive, said first and second unchanged regions being aligned with each other to define a current channel extending through said preselected region of said active region; and

Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region (nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the etching of the plurality of pits 58 and 58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.

said means for selectively exposing a portion of said second current blocking layer further comprises at least one etched depression extending from said first surface of said laser into the body of said laser structure and

Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12,

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| <p>through said second current blocking layer to expose a portion of said second current blocking layer to said preselected agent during manufacture of said laser structure.</p> | <p>according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F.</p> |
| <p>Claim 60</p> <p>The laser structure of claim 57, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first current blocking layer being exposed at a surface of said lasing portion.</p> | <p>Substrate portion: Column 7, lines 15, 23, 31, <i>inter alia</i>, referring to Figs. 5A-F (illustrating substrate 82). See also Fig. 7 (substrate 182). Referring to Figs. A-F, lasing portion 86 is disposed on substrate portion 82. See also Column 9, line 21. See Fig. 6J displaying interconnect metal 100, where oxidation barrier (first current blocking layer 28) is exposed at the surface of the lasing portion 86. Interconnect metal 100 is comprised of the contact support portion 96 and the bridging portion 100 disposed on the substrate portion. And see column 5, lines 52-55, referring to Fig. 1D (illustrating conductive element 40 comprising a plurality of oxidizing layers 12, teaching that a plurality of layers are exposed at the surface of the lasing portion).</p> |
| <p>Claim 61</p> <p>The laser structure of claim 59, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said lasing portion.</p> | <p>Substrate portion: Column 7, lines 15, 23, 31, <i>inter alia</i>, referring to Figs. 5A-F (illustrating substrate 82). See also Fig. 7 (substrate 182). Referring to Figs. A-F, lasing portion 86 is disposed on substrate portion 82. See also Column 9, line 21. See Fig. 6J displaying interconnect metal 100, where oxidation barrier (first current blocking layer 28) is exposed at the surface of the lasing portion 86. Interconnect metal 100 is comprised of the contact support portion 96 and the bridging portion 100 disposed on the</p> |

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| | substrate portion. And see column 5, lines 52-55, referring to Fig. 1D (illustrating conductive element 40 comprising a plurality of oxidizing layers 12, teaching that a plurality of layers are exposed at the surface of the lasing portion). |
| Claim 62 | |
| The laser structure of claim 57, wherein: said preselected agent is an oxidizing agent and said physical change is oxidation. | Column 4, lines 60-66, column 5, lines 1-6, <i>inter alia</i> . |
| Claim 63 | |
| The laser structure of claim 62, wherein: said oxidizing agent is water vapor. | Column 9, line 8 (oxidation performed, for example, at 425°C in a water vapor rich atmosphere). |
| Claim 64 | |
| The laser structure of claim 57, wherein: said preselected agent is an etchant. | Column 6, line 14. See Fig. 2B (pit 58 is typically formed by etching); column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F. |
| Claim 65 | |
| The laser structure of claim 64, wherein: said etchant is an acid. | Known in the art. |
| Claim 66 | |
| The laser structure of claim 57, wherein said first means for selectively exposing further comprises: four etched depressions extending from said first surface of said laser structure and through said first current blocking layer to expose a plurality of portions of said current blocking layer to said preselected agent during manufacture of said laser structure. | Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174. |
| Claim 67 | |
| The laser structure of claim 57, further comprising: an first mirror structure comprising a first plurality of layers; | Column 7, line 19. See Fig. 5A (oxidized top mirror 88 comprising oxidized layers 89 and semiconductor layers 80). See also Column 7, lines 27-29, Fig. 5B (dielectric top mirror 106 |

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| | comprising low-index dielectric layers 107 and high-index dielectric layers 108); and see Fig. 5C (illustrating top mirror 112); Fig. 5D (illustrating oxidized top mirror 122 comprising oxidizing layers 123 and semiconductor layers 124); Fig. 5E (illustrating dielectric top mirror 134 comprising low-index dielectric layers 135 and high-index dielectric layers 136). |
| a second mirror structure comprising a second plurality of layers, said active region being disposed between said first and second mirror structures. | Column 7, line 16. See Fig. 5A (semiconductor bottom mirror 84, where active region is disposed between 1st and 2nd mirror structures). See also Column 7, line 24, Fig. 5B (illustrating active region being disposed between top mirror 106 and semiconductor bottom mirror 84); column 7, lines 32-35, referring to Fig. 5C (illustrating active region 86 being disposed between semiconductor bottom mirror 84 and semiconductor top mirror 112); and column 7, lines 34-43, referring to Fig. 5D (illustrating active region 86 being disposed between oxidized bottom mirror 118 comprising alternating oxidized layers 119 and semiconductor layers 120 and oxidized top mirror 122 comprising oxidized layers 123 and semiconductor layers 124). |
| Claim 68 | |
| The laser structure of claim 59, wherein: said means for selectively exposing a portion of said second current blocking layer further comprises four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said second current blocking layer to expose a plurality of portions of said second current blocking layer to said preselected agent during manufacture of said laser structure. | Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for |

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| | holes 174. |
| Claim 69 | |
| A laser structure, comprising: an active region; | Column 7, lines 16, 24, 32,33, 48, and 57. See Figs. 5A-F (86). |
| a first electrical contact disposed on a first surface of said laser structure; | Column 7, lines 21, 29-30, 36, 44, 53, and 60. See Figs. 5A-F (96). |
| a second electrical contact, said active region being disposed between said first and second electrical contacts, said laser structure being a vertical cavity surface emitting laser; | Column 7, lines 22 and 30. See Figs. 5A-C, which illustrate active region 86 being disposed between top contact 96 and bottom contact 98. See also Column 7, lines 45, 53 and 60. See Figs. 5D-F (128). Figs. D-F illustrate active region 86 being disposed between top contact 96 and bottom contact 128. As to being a VSEL, see Column 6, lines 43. See Figs. 5A (80), 5B (102), 5C (110), 5D (116), 5E (130) and 5F (138). Fig. 6 illustrates an example of a processing method to produce VSELS. See also Column 9, line 123; Fig. 7 (180). |
| a first current blocking layer, said first current blocking layer being subject to oxidation when exposed to an oxidizing agent; | Column 6, lines 13-14, referring to Fig. 2B (illustrating oxidizing layer 12). See also Column 7, lines 28-34. See Figs. 5A-F (teaching oxidized portions 28). |
| a second current blocking layer, said second current blocking layer being subject to oxidation when exposed to said oxidizing agent; | Column 9, lines 4-9. See Fig. 6G (175). See also column 5, lines 52-55, Fig. 1D (a plurality of oxidizing layers 12). Figs. 5A-F illustrate a plurality of current blocking layers 28, each being oxidized portions of the current blocking layer being subject to oxidation when exposed to an oxidizing agent. |
| a first means for selectively exposing a portion of said first current blocking layer to said oxidizing agent to define a first nonoxidized region of said first current blocking layer surrounded by a first oxidized region of said first current blocking layer, said first nonoxidized region of said first current blocking layer being aligned with a preselected region of said active region, said first oxidized region being electrically insulative, said first nonoxidized region being electrically conductive; | Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region |

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| | <p>(nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the etching of the plurality of pits 58 and 58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.</p> |
| <p>second means for selectively exposing a portion of said second current blocking layer to said oxidizing agent to define a second nonoxidized region of said second current blocking layer surrounded by a second oxidized region of said second current blocking layer, said second nonoxidizing region of said second current blocking layer being aligned with said preselected region of said active region, said second oxidized region being electrically insulative, said second nonoxidized region being electrically conductive, said first and second nonoxidized regions being aligned with each other to define a current channel extending through said preselected region of said active region; and</p> | <p>Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region (nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the etching of the plurality of pits 58 and</p> |

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| | <p>58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.</p> |
| <p>wherein said first means for selectively exposing and said second means for selectively exposing include at least one etched depression extending from said first surface of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a portion of said first and second current blocking layers to said preselected agent during manufacture of said laser structure.</p> | <p>Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174.</p> |
| Claim 70 | |
| <p>The laser structure of claim 69, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said</p> | <p>Substrate portion: Column 7, lines 15, 23, 31, <i>inter alia</i>, referring to Figs. 5A-F (illustrating substrate 82). See also Fig. 7 (substrate 182). Referring to Figs. A-F, lasing portion 86 is disposed on substrate portion 82. See also</p> |

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| bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said lasing portion. | Column 9, line 21. See Fig. 6J displaying interconnect metal 100, where oxidation barrier (first current blocking layer 28) is exposed at the surface of the lasing portion 86. Interconnect metal 100 is comprised of the contact support portion 96 and the bridging portion 100 disposed on the substrate portion. And see column 5, lines 52-55, referring to Fig. 1D (illustrating conductive element 40 comprising a plurality of oxidizing layers 12, teaching that a plurality of layers are exposed at the surface of the lasing portion). |
| Claim 71 | |
| The laser structure of claim 70, wherein: said first and second current blocking layers comprise an aluminum bearing material. | Column 5, lines 18-23. See Fig. 1B (exemplary materials are AlAs for oxidizing layer 24). Additionally, see column 7, lines 4-14 which discuss the abundance of examples of the oxidizing materials primarily comprising Al as the group III element. |
| Claim 72 | |
| The laser structure of claim 70, wherein: said oxidizing agent is water vapor. | Column 9, line 8 (oxidation performed, for example, at 425°C in a water vapor rich atmosphere). |
| Claim 73 | |
| The laser structure of claim 69, wherein: said first and second means for selectively exposing further include four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a plurality of portions of said current blocking layers to said preselected agent during manufacture of said laser structure. | Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174. |
| Claim 74 | |
| A laser structure, comprising: an active region; | Column 7, lines 16, 24, 32,33, 48, and 57. See Figs. 5A-F (86). |

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| a first electrical contact disposed on a first surface of said laser structure; | Column 7, lines 21, 29-30, 36, 44, 53, and 60. See Figs. 5A-F (96). |
| a second electrical contact, said active region being disposed between said first and second electrical contacts, said laser structure being a vertical cavity surface emitting laser; | Column 7, lines 22 and 30. See Figs. 5A-C, which illustrate active region 86 being disposed between top contact 96 and bottom contact 98. See also Column 7, lines 45, 53 and 60. See Figs. 5D-F (128). Figs. D-F illustrate active region 86 being disposed between top contact 96 and bottom contact 128. As to being a VSCSEL, see Column 6, lines 43. See Figs. 5A (80), 5B (102), 5C (110), 5D (116), 5E (130) and 5F (138). Fig. 6 illustrates an example of a processing method to produce VSCELs. See also Column 9, line 123; Fig. 7 (180). |
| a first current blocking layer, said first current blocking layer being subject to oxidation when exposed to an oxidizing agent; | Column 6, lines 13-14, referring to Fig. 2B (illustrating oxidizing layer 12). See also Column 7, lines 28-34. See Figs. 5A-F (teaching oxidized portions 28). |
| a second current blocking layer, said second current blocking layer being subject to oxidation when exposed to said oxidizing agent; | Column 9, lines 4-9. See Fig. 6G (175). See also column 5, lines 52-55, Fig. 1D (a plurality of oxidizing layers 12). Figs. 5A-F illustrate a plurality of current blocking layers 28, each being oxidized portions of the current blocking layer being subject to oxidation when exposed to an oxidizing agent. |
| first means for selectively exposing a portion of said first current blocking layer to said oxidizing agent to define a first nonoxidized region of said first current blocking layer surrounded by a first oxidized region of said first current blocking layer, said first nonoxidized region of said first current blocking layer being aligned with a preselected region of said active region, said first oxidized region being electrically insulative, said first nonoxidized region being electrically conductive; | Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region (nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the |

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| | <p>etching of the plurality of pits 58 and 58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.</p> |
| <p>second means for selectively exposing a portion of said second current blocking layer to said oxidizing agent to define a second nonoxidized region of said second current blocking layer surrounded by a second oxidized region of said second current blocking layer, said second nonoxidized region of said second current blocking layer being aligned with said preselected region of said active region, said second oxidized region being electrically insulative, said second nonoxidized region being electrically conductive, said first and second nonoxidized regions being aligned with each other to define a current channel extending through said preselected region of said active region; and</p> | <p>Column 8, lines 54-48, referring to Fig. 6E (illustrating an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. As discussed in column 6, lines 14-19, etching is also involved to form a plurality of pits, 58 and 58', or more, may be formed which may be nominally identical or of different depths as illustrated by pit 58' in Fig. 2B. Fig. 6F illustrates not only the first means for selectively exposing a portion of said first and second current blocking layers (oxidized layers 28 of Figs. 5A-F and 24 of Fig. 6F) to a preselected agent to define a first unchanged region (nonoxidized layers 26 of Figs. 5A-F and 26 of Fig. 6F) of the plurality of current blocking layers, but also the second means by incorporating the etching of the plurality of pits 58 and 58', or more, as discussed above. Fig. 6F illustrates that a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches</p> |

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| | <p>through oxidizing layers 24 and nonoxidizing layers 26. Additionally, as discussed in column 9, lines 4-9, Fig. 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing a plurality of unchanged regions of the plurality of current blocking layers 175 and the plurality of oxidized mirror layers 176. As to the conductive/insulative regions, see column 5, lines 29-31, referring to Fig. 1B (interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive). See also column 6, lines 23-28, referring to Fig. 3 (oxidation barriers 18 and 18'); column 10, lines 59-63, with reference to Fig. 9.</p> |
| <p>wherein said first and second means for selectively exposing further comprise at least one etched depression extending from said first surfaces of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a portion of said current blocking layers to said preselected agent during manufacture of said laser structure.</p> | <p>Column 6, lines 5-22. See Fig. 2 (describing that pit 58 is typically formed by etching, where 58 typically extends at least into, or very near to, oxidizing layer 12). Oxidizing layer 12, according to Column 5, lines 52-55, and Fig 1D, is made up of a plurality of oxidizing layers. See also Column 6, line 14, referring to Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174.</p> |
| Claim 75 | |
| <p>The laser structure of claim 74, wherein: said laser structure comprises a substrate portion, a lasing portion disposed on said substrate portion, a contact support portion disposed on said substrate portion, and a bridging portion disposed on said substrate portion, said bridging portion connected between said lasing portion and said contact support portion, said first and second current blocking layers being exposed at a surface of said</p> | <p>Substrate portion: Column 7, lines 15, 23, 31, <i>inter alia</i>, referring to Figs. 5A-F (illustrating substrate 82). See also Fig. 7 (substrate 182). Referring to Figs. A-F, lasing portion 86 is disposed on substrate portion 82. See also Column 9, line 21. See Fig. 6J displaying interconnect metal 100, where oxidation barrier (first current blocking layer 28) is exposed at the</p> |

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| lasing portion, said first and second current blocking layers comprise an aluminum bearing material, said oxidizing agent being water vapor. | surface of the lasing portion 86. Interconnect metal 100 is comprised of the contact support portion 96 and the bridging portion 100 disposed on the substrate portion. And see column 5, lines 52-55, referring to Fig. 1D (illustrating conductive element 40 comprising a plurality of oxidizing layers 12, teaching that a plurality of layers are exposed at the surface of the lasing portion). Additionally, as to the aluminum bearing material attribute, see column 5, lines 13-23 (describing AlAs as an exemplary material for oxidizing layer 28 of Fig. 1B); see also column 7, lines 4-14 which discuss the abundance of examples of the oxidizing materials primarily comprising Al as the group III element. Finally, see column 9, line 8 (noting that oxidation can be performed, for example, at 425°C in a water vapor rich atmosphere). |
| Claim 76 | |
| The laser structure of claim 74, further comprising: a plurality of etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first current blocking layer to expose a plurality of portions of said current blocking layer to said oxidizing agent during manufacture of said laser structure. | Column 6, line 14. See Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig. 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174. |
| Claim 77 | |
| The laser structure of claim 74, wherein: the first and second means for exposing further include four etched depressions extending from said first surface of said laser structure into the body of said laser structure and through said first and second current blocking layers to expose a plurality of portions of said current blocking layers to said preselected agent during manufacture of said laser structure. | Column 6, line 14. See Fig. 2B (pit 58 is typically formed by etching). Further, column 6, lines 15-18, and Fig. 2B, teach that a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. See also column 8, lines 54-58, Fig. 6E (holes 168 are etched through masks 170); Column 8, line 66-67, Fig. 6F, for holes 174. |

Application for

United States Letters Patent

of

Jack L. Jewell

for

CONDUCTIVE ELEMENT WITH LATERAL OXIDATION BARRIER

CONDUCTIVE ELEMENT WITH LATERAL OXIDATION BARRIER

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to semiconductor devices whose current flow is controlled by layers which are oxidized over part of their areas, and more particularly to layers which have been modified in order to control the extent and shape of the oxidized regions, and most particularly to devices, especially lasers and vertical cavity
10 surface emitting lasers (VCSELs), which utilize such conductive elements. The present invention furthermore relates to the formation of VCSELs which emit at visible and infrared wavelengths which reside on non-GaAs substrates, and VCSELs whose emission wavelengths are precisely controlled.

Description of the Prior Art

15 Vertical-cavity surface-emitting lasers (VCSELs) whose current flow is controlled by lateral oxidation processes show the best performances of any VCSELs in terms of low threshold current and high efficiency. In oxidized VCSELs the
20 oxidation occurs in the lateral direction from the sides of etched mesas in the VCSEL wafers, typically under the conditions of 425°C temperature with high water-vapor content. Presently however, the lateral oxidation process is controlled only through careful control of the timing, temperature, and the sizes of the mesas. This presents
25 difficulties in the manufacturability of such VCSELs, because the current apertures may not be the same from wafer to wafer, or even within a single wafer. Furthermore, since there is no definite stopping mechanism for the oxidation process other than removal from the oxidation environment, the reliability of oxidized VCSELs has not been very high. VCSELs or any other light emitting devices
30 employing laterally oxidized layers have been strictly limited only to structures which have been grown upon gallium arsenide (GaAs) substrates and emit light at wavelengths limited to the region bounded by 0.63 μm and 1.1 μm . Since VCSELs are presently the subject of intense research and development, a great deal of results and advancements are published monthly.

are presently the subject of intense research and development, a great deal of results and advancements are published monthly.

Most reports of the oxidation process describe oxidation in layers of aluminum arsenide (AlAs) or aluminum gallium arsenide ($\text{Al}_x\text{Ga}_{1-x}\text{As}$) where the Al concentration, x , is close to unity. As reported by Choquette, et al. in "Low threshold Voltage Vertical-Cavity Lasers Fabricated by Selective Oxidation," which appeared in Electronics Letters, volume 24, pp. 2043-2044, 1994, reducing the Al concentration from $x=1.0$ to $x=0.96$ reduces the oxidation rate by more than one order of magnitude. At $x=0.87$, the oxidation rate is reduced by two orders of magnitude compared to $x=1.0$. Due to the extreme sensitivity of the oxidation rate to the Al concentration and the fact that Al concentration may vary from wafer to wafer or even over the area of a single wafer, the manufacturability of oxidized VCSELs has been questioned. In the very recent publication by Choquette et al., entitled "Fabrication and Performance of Selectively Oxidized Vertical-Cavity Lasers," which appeared in IEEE Photonics Technology Letters, vol. 7, pp. 1237-1239, (November, 1995), this problem was noted followed by the observation that "Therefore, stringent compositional control may be necessary for wafer scale manufacture of uniformly sized oxide apertures."

A limited form of lateral control of oxidation is reported in the publication by Dallesasse, et al. entitled "Hydrolyzation Oxidation of $\text{Al}_x\text{Ga}_{1-x}\text{As-AlAs-GaAs}$ Quantum Well Heterostructures and Superlattices," which appeared in Applied Physics Letters, volume 57, pp. 2844-2846, 1990. The same work is also described in U.S. Patent No.'s 5,262,360 and 5,373,522, both by Holonyak and Dallesasse. In that work, GaAs-AlAs superlattices were interdiffused in selected regions by impurity-induced layer disordering (IILD). The interdiffusion was essentially complete in the selected regions, thus the interdiffused regions comprised an AlGaAs compound having an Al concentration being approximately uniform and equal to the average Al concentration of the original constituent AlAs and GaAs layers. The oxidation proceeded through the superlattice regions but not significantly into the interdiffused regions. The superlattice was not doped and contained no other structure from which to fabricate

any electronic or optoelectronic device. No attempt was made to form any kind of conductive aperture or boundary.

Implantation enhanced interdiffusion (IEI) is another method for interdiffusing thin semiconductor layers and is described by Cibert et al. in the publication entitled
5 "Kinetics of Implantation Enhanced Interdiffusion of Ga and Al at GaAs- $\text{Al}_x\text{Ga}_{1-x}\text{As}$ Interfaces," which appeared in Applied Physics Letters, volume 49, pp. 223-225, 1986.

Due to the much lower refractive index of aluminum oxide compared to AlAs (about 1.6 compared to 3.0) oxidation of an AlAs layer within a VCSEL cavity shifts the cavity resonance to a shorter wavelength as reported by Choquette et al. in "Cavity
10 Characteristics of Selectively Oxidized Vertical-Cavity Lasers," which appeared in Applied Physics Letters, volume 66, pp. 3413-3415, in 1995.

Formation of VCSELs which emit a wavelengths longer than about
1 1 μ m has been difficult in the prior art. Despite numerous efforts toward
15 developing 1.3-1.55 μ m emitting VCSELs, only recently as room-temperature continuous-wave emission been reported as in the publication by Babic et al. entitled "Room-Temperature Continuous-Wave Operation of 1.54- μ m Vertical-Cavity Lasers," which appeared in IEEE Photonics Technology Letters, vol. 7, pp. 1225-1227 (November, 1995).
20 In that work, fabrication was accomplished by fusing semiconductor mirrors and active regions epitaxially grown on three separate substrates. Another approach to forming 1.3-1.55 μ m emitting VCSELs is to grow semiconductor mirrors of aluminum arsenide antimonide (AlAsSb) and aluminum gallium arsenide antimonide (AlGaAsSb) on indium
25 phosphide (InP) substrates as reported by Blum et al., in the publication entitled "Electrical and Optical Characteristics of AlAsSb/GaAsSb Distributed Bragg Reflectors for Surface Emitting

Lasers," which appeared in Applied Physics Letters, vol. 67, pp. 3233-3235 (November 1995).

SUMMARY OF THE INVENTION

5 It is therefore an object of the invention to provide a partially oxidized electrically conductive element in which the lateral extent of the oxidation is controlled.

It is another object of the invention to provide an oxidized VCSEL which is manufacturable.

10 It is yet another object of the invention to provide an oxidized VCSEL which is reliable.

It is yet another object of the invention to provide an oxidized VCSEL whose emission wavelength is precisely controlled on a fine scale.

It is yet another object of the invention to provide an oxidized VCSEL which emits light at a wavelength greater than 1.2 μm .

15 According to one broad aspect of the invention, there is provided a conductive element which is substantially conducting in one region and which is oxidized and therefore substantially nonconducting in another region, the conducting region having been made resistive to oxidation compared to the nonconducting region.

20 According to another broad aspect of the invention, there is provided a VCSEL whose current flow is constrained by a conductive aperture surrounded by oxidized material having predetermined lateral dimensions comprising: a substrate, a first mirror situated above the substrate, a first conductive spacer situated above the first mirror and below the light emitting material, a second conductive spacer situated above the

light emitting material; a conductive element comprising an oxidizing layer which has been oxidized in a first non-conducting region and which has been modified to resist oxidation in a second, conductive region; a second mirror situated above the second conductive spacer, a first contact for electrically contacting to the conducting element, and a second contact for electrically contacting a material of a second conductive type, the first and second mirrors and all material between forming an optical cavity having a cavity resonance at a nominal wavelength, and means for injecting electrical current through the conducting element and into the light emitting material, thereby causing the VCSEL to emit a beam of light at or near nominal wavelength.

According to another broad aspect of the invention, the emission wavelengths of such VCSELs are controlled by controlling aperture diameters of the conductive elements and the total thickness of oxidizing layer or layers.

According to another broad aspect of the invention, VCSELs whose emission wavelengths are longer than 1.2 μm are formed by oxidizing at least portions of the first (bottom) mirror or by forming a conductive aperture with a controlled oxidation process.

Other objects and features of the present invention will be apparent from the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in conjunction with the accompanying drawings, in which:

Figure 1A is an isometric view of a controlled oxidation conductive element (COCE) illustrating its predetermined laterally oriented regions;

Figure 1B is an isometric view of a COCE illustrating the interdiffusion of the oxidizing layer with an adjacent layer, optionally brought about by an external beam of energy;

Figure 1C is an isometric view of a COCE which forms a current aperture;

5 Figure 1D is an isometric view of a COCE having a plurality of oxidizing layers;

Figure 1E is an isometric cross-sectional view of a COCE in which the oxidation barrier forms an annulus;

10 Figure 1F is an isometric view of a COCE in which the oxidation barrier is shaped to enhance emission in a predetermined combination of spatial modes;

Figure 2A is an isometric view of a COCE which has been etched into a mesa;

Figure 2B is an isometric view of a COCE which is substantially planar except for nearby etched pits;

15 Figure 3 is an isometric view of a plurality of COCE's illustrating isolation of one COCE from another;

Figure 4 is an isometric view of an edge-emitting laser or light emitting diode incorporating a COCE;

Figure 5A is a cross-sectional side view of a VCSEL incorporating a COCE, a semiconductor bottom mirror and an oxidized top mirror;

20 Figure 5B is a cross-sectional side view of a VCSEL incorporating a COCE, a semiconductor bottom mirror and a dielectric top mirror;

Figure 5C is a cross-sectional side view of a VCSEL incorporating a COCE, a semiconductor bottom mirror and a semiconductor top mirror;

Figure 5D is a cross-sectional side view of a VCSEL incorporating a COCE, an oxidized bottom mirror and an oxidized top mirror;

5 Figure 5E is a cross-sectional side view of a VCSEL incorporating a COCE, an oxidized bottom mirror and a dielectric top mirror;

Figure 5F is a cross-sectional side view of a VCSEL incorporating a COCE, an oxidized bottom mirror and a semiconductor top mirror;

10 Figure 6A is a cross-sectional side view of a VCSEL illustrating the layer structure and an ion implantation step;

Figure 6B is a cross-sectional side view of a VCSEL illustrating an annealing and interdiffusion step;

Figure 6C is a cross-sectional side view of a VCSEL illustrating an epitaxial regrowth step;

15 Figure 6D is a cross-sectional side view of a VCSEL illustrating an isolation step;

Figure 6E is a cross-sectional side view of a VCSEL illustrating an etch and ohmic contacting step;

20 Figure 6F is a cross-sectional side view of a VCSEL illustrating a second etch step;

Figure 6G is a cross-sectional side view of a VCSEL illustrating an oxidation step;

Figure 6H is a cross-sectional side view of a VCSEL illustrating an interconnect metal deposition step;

5 Figure 6I is a cross-sectional side view of a VCSEL illustrating a bottom ohmic contacting step;

Figure 6J is a top planar view of a VCSEL illustrating the various metals and apertures formed;

10 Figure 7 is a cross-sectional side view illustrating one embodiment of a VCSEL designed for emission at a wavelength greater than $1.2\text{ }\mu\text{m}$;

Figure 8A is a top planar view schematically illustrating relative aperture sizes of VCSELs distributed over a wafer;

Figure 8B is a top planar view schematically illustrating relative aperture sizes of VCSELs distributed over a wafer;

15 Figure 8C is a top planar view schematically illustrating relative aperture sizes of VCSELs distributed over a chip; and

Figure 9 is a cross-sectional side view of a lateral oxidation barrier residing over a light-emitting material layer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the Figures, wherein like reference characters indicate like elements throughout the several views and, in particular, with reference to Figure 1, a controlled oxidation conductive element (COCE) is illustrated in accordance with the present invention. Figure 1A illustrates COCE 10, chiefly comprising oxidizing layer 12. Oxidizing layer 12 comprises oxidized portion 14 within first non-conductive region 16 and oxidation barrier 18 within second conductive region 20. Oxidation barrier 18 is resistant to oxidation compared to oxidized portion 14, made so by its modification, and thereby defines second conductive region 20. Oxidation barrier 18 of oxidizing layer 12 is substantially electrically conductive, while oxidized portion 14 is electrically resistive. Cap layer 21 lies above oxidizing layer 12. Preferably, first region 16 and second region 20 are defined by photolithography.

Figure 1B illustrates conductive element 22, chiefly comprising oxidizing layer 24 and nonoxidizing layers 26. Oxidizing layer 24 comprises oxidized portion 28 defined by first region 30 and interdiffused portion 32 defined by second region 34. Interdiffused portion 32 is resistant to oxidation compared to oxidized portion 28, made so by its interdiffusion with nonoxidizing layer 26 in second region 34; thus interdiffused portion 32 forms an oxidation barrier. Preferably, first region 30 and second region 34 are defined by photolithography. Exemplary materials are AlAs for oxidizing layer 24 and GaAs for nonoxidizing layer 26. More generally, oxidizing layer 24 is a material from the set of semiconductors known as group III-V materials, in which the group III constituent is primarily Al, while nonoxidizing layers 26 are III-V materials in which the group III constituent is not primarily Al. As was described in the prior art, the presence of even small amounts of non-Al group-III elements such as Ga may greatly inhibit oxidation. Thus the interdiffusion of oxidizing layer 24 and nonoxidizing layer 26 introduces non-Al elements into oxidizing layer 24, rendering it resistive to oxidation. Interdiffused portion 32 of oxidizing layer 24 is substantially electrically conductive, while oxidized portion 28 is electrically resistive. Preferably, first region 30 and second region 34 are defined

by photolithography. The interdiffusion of oxidizing layer 24 and nonoxidizing layer 26 may be brought about, for example, by beam 36, followed by an annealing process. Beam 36 may comprise, for example, an ion beam, an optical beam, or an ion diffusion beam. Oxidizing layer(s) 24 and nonoxidizing layer(s) 26 are preferably thick enough, e.g. $>50\text{\AA}$, to allow lateral oxidation over micron lengths in reasonable times. On the other hand, interdiffusion is much more readily accomplished when the layers are thin, preferably well under 1000\AA . The interdiffusion may be accomplished by several techniques, including impurity-induced layer disordering (IILD), implantation enhanced interdiffusion (IEI), and localized optical heating. Both IILD, IEI and localized optical heating may be patterned laterally by photolithography or other means.

Figure 1C illustrates conductive element 38 in which second region 20 is in the form of an aperture. Modified portion 18 is not shown since it is surrounded by oxidized portion 14, but it is illustrated in Figure 1E. Figure 1D illustrates conductive element 40 comprising a plurality of oxidizing layers 12 which are shown as being nominally the same, however it is possible to have non-identical oxidizing layers 12, for example with different thicknesses or compositions. Figure 1E illustrates conductive element 42 in which oxidation barrier 18 and second region 20 are each in the form of an annulus. Conductive element 42 additionally comprises third region 44 in which unaffected portion 46 is nominally unaffected either by the modification of oxidizing layer 12, for example by interdiffusion, or by the oxidation process. Figure 1F illustrates conductive element 48 in which second region 20 has a complex pattern, for example to enhance light emission in complex cavity modes. It should be appreciated that the pattern illustrated is merely exemplary of any complex pattern that may be desired. A complex pattern is defined as any pattern which is not a square or a circle.

Referring now to Figure 2 there are shown two geometries through which oxidizing layer 12 may be accessed to enable the oxidation process. Figure 2A illustrates conductive element 50 wherein oxidizing layer 14 is capped by cap layer

52. In order for oxidizing layer to be accessed, sidewall 54 is formed. Sidewall 54 is typically formed by etching and typically extends at least into, or very near to, oxidizing layer 12. In conducting element 50, sidewall 54 completely surrounds second region 20, forming a mesa which resides on substrate 55. In the present invention, it is not necessary for sidewall 54 to have the same shape as second region 20 as is shown in Figure 2A but it should be appreciated that this is also possible. Figure 2B illustrates conductive element 56 in which oxidizing layer 12 is accessed by pit 58. Pit 58 is typically formed by etching and typically extends at least into, or very near to, oxidizing layer 12. As shown in Figure 2B, a plurality of pits 58 and 58', or more, may be formed which may be nominally identical or of different shapes and/or depths as illustrated by pit 58'. An advantage of forming pits, for example pit 58, is that interconnect metallization may be added subsequently onto a planar surface without the need to deposit metal on the sidewall of a mesa.

Referring now to Figure 3 there is shown array 60 comprising a plurality of oxidation barriers 18. In order to prevent electrical current flow between different conductive elements, cap layer 52 is rendered nonconductive in nonconductive regions 62, for example through ion implantation. It should be appreciated that the apertures formed by elements 20 and 20' may be nominally identical or they may be different sizes and/or shapes as shown.

Referring now to Figure 4, there is shown light source 64 which incorporates oxidation barrier 18 and oxidized portion 14. Light source 64 may be, for example, a light emitting diode (LED) or an edge-emitting laser. Light source 64 also incorporates elements well known in the art such as substrate 66, first cladding layer 68, active layer 70, second cladding layer 72, first contact 74 and second contact 76. In response to a current flow, light source 64 emits a beam of light, for example light beam 78 as in an edge-emitting laser.

Referring now to Figure 5, there are shown exemplary configurations of light emitters in accordance with the present invention. The light emitters illustrated in

Figure 5 may be VCSELs or LEDs. In the case of LEDs, some elements depicted may be deleted, for example one or both of the mirrors. Furthermore, the substrate may be deleted for any configuration of either VCSEL or LED. The examples shown in Figure 5 are not meant to limit the present invention to only the precise configurations illustrated. For example, if the light emitters emit light downward through the substrate, a metal layer may be added to the top mirror to provide increased reflectivity with minimal layers. Typically, the light emitters may have a bottom mirror and a top mirror, by convention the bottom mirror referring to the mirror which was originally first deposited onto the substrate. Bottom mirrors are preferably either conventional semiconductor mirrors comprising alternating semiconductor layers, or oxidized comprising alternating layers of semiconductor material and oxidized semiconductor material. Since the oxidation occurs after growth of the active region, both types of mirror allow epitaxial growth of high quality active regions. Top mirrors may also have either of these two configurations, and additionally may comprise dielectric and/or metallic materials since epitaxial growth above them is not generally necessary. The two general types of bottom mirrors and three general types of top mirrors yield six general configurations for the examples illustrated in Figure 5. Due to the large number of oxidized layers in some of the illustrations, the oxidized layers are identified by drawing fill texture rather than by numbers. The substrate, whether present or removed, may comprise for example GaP, GaAs, InP, InAs, GaSb or InSb. The oxidized layers are typically materials primarily comprising Al as the group-III element, for example AlP, AlAsP, AlGaAs, AlGaAsP, AlAs, AlAsP, AlPSb, AlGaPSb, InAlAs, InAlGaAs, InAlGaAsP, AlAsSb, AlAsSbP, AlGaAsSb, InGaAlAsSbP, AlSb, AlPSb, AlGaP and InAlGaAsSb. Nonoxidizing layers may comprise GaAs, AlGaAs, InAlGaAs, InAlGaP, GaAsSb, GaPSb, AlGaPS, InGaAs, or InGaAsP, AlSb, AlPSb, AlGaP and InAlGaAsSb. Typically, Al will comprise at least 60% of the group-III material in oxidizing layer 12 as illustrated Figures 1 and 2.

Figure 5A illustrates light emitter 80 comprising substrate 82, semiconductor bottom mirror 84, first spacer 146, active region 86, second spacer 148, nonoxidizing

layers 26, oxidation barrier 32 surrounded by oxidized portions 28, conductive spacer 160, oxidized top mirror 88 comprising oxidized layers 89 and semiconductor layers 90, wafer top surface 92, electrically insulating regions 94, top contact 96, bottom contact 98, and interconnect metal 100. Figure 5B illustrates light emitter 102 comprising substrate 82, semiconductor bottom mirror 84, first spacer 146, active region 86, second spacer 148, nonoxidizing layers 26, oxidation barrier 32 surrounded by oxidized portions 28, conductive spacer 160, wafer top surface 104, dielectric top mirror 106 comprising low-index dielectric layers 107 and high-index dielectric layers 108, electrically insulating regions 94, top contact 96, bottom contact 98, and interconnect metal 100. Figure 5C illustrates light emitter 110 comprising substrate 82, semiconductor bottom mirror 84, first spacer 146, active region 86, second spacer 148, nonoxidizing layers 26, oxidation barrier 32 surrounded by oxidized portions 28, semiconductor top mirror 112, wafer top surface 114, electrically insulating regions 94, top contact 96, bottom contact 98, and interconnect metal 100. Figure 5D illustrates light emitter 116 comprising substrate 82, oxidized bottom mirror 118 comprising alternating oxidized layers 119 and semiconductor layers 120, first spacer 146, active region 86, second spacer 148, nonoxidizing layers 26, oxidation barrier 32 surrounded by oxidized portions 28, conductive spacer 160, oxidized top mirror 122 comprising oxidized layers 123 and semiconductor layers 124, wafer top surface 126, top contact 96, bottom contact 128, and interconnect metal 100. Figure 5E illustrates light emitter 130 comprising substrate 82, oxidized bottom mirror 118 comprising oxidized layers 119 and semiconductor layers 120, first spacer 146, active region 86, second spacer 148, nonoxidizing layers 26, oxidation barrier 32 surrounded by oxidized portions 28, conductive spacer 160, wafer top surface 132, dielectric top mirror 134 comprising low-index dielectric layers 135 and high-index dielectric layers 136, top contact 96, bottom contact 128, and interconnect metal 100. Figure 5F illustrates light emitter 138 comprising substrate 82, oxidized bottom mirror 118 comprising oxidized layers 119 and semiconductor layers 120, first spacer 146, active region 86, second spacer 148, nonoxidizing layers 26, oxidation barrier 32 surrounded by oxidized portions 28, semiconductor top mirror 140, wafer top surface 142, top contact 96, bottom contact 128, and interconnect metal 100.

Referring now to Figure 6 there is shown an example of a processing method to produce VCSELs or LEDs by the inventive method. There are many means and methods to fabricate optoelectronic devices which use laterally controlled oxidation; the method illustrated in Figure 6 is only one example. Individual steps of the example method may be incorporated into alternative fabrication methods. To simplify and clarify the description, only new features to the structure are identified in each figure throughout Figures 6A through 6I. Figures 6A through 6I are cross-sectional side views of the device under fabrication, while Figure 6J is a top view of the completed device. Prior to fabrication, it may be preferable to pattern the wafer with alignment marks since the first step does not leave obvious patterns to which the next steps in the process may be aligned.

Figure 6A shows the first epitaxial structure 144 comprising substrate 82, semiconductor bottom mirror 84, first spacer 146, active region 86, second spacer 148, oxidizing layers 24, and nonoxidizing layers 26. Also shown is photoresist mask 154 which shields most of the area from ion beam 156. Ion beam 156 impinges with ion energy predetermined to penetrate into oxidizing layers 150 and nonoxidizing layers 152, but preferably not into active region 86.

Figure 6B illustrates an annealing/interdiffusion step in which only the implanted regions are interdiffused, thereby forming oxidation barrier 32, analogous to oxidation barrier 18 of Figures 1A, 1E, 3, 4 and 5. The annealing step of Figure 6B may, for example, comprise a rapid thermal anneal at 950 degrees Celsius for 2 minutes. The process for the step illustrated in Figure 6B may be that of implantation enhanced interdiffusion. Alternatively, the interdiffusion may be accomplished by impurity induced layer disordering or similar processes. Another alternative is that the interdiffusion be accomplished by localized heating by an intense optical beam whose optical penetration is significant mainly through oxidizing layers 24 and nonoxidizing layers 26. Localized heating by optical beams may also be used to accomplish the annealing process.

Figure 6C illustrates deposition by epitaxial regrowth of conductive spacer 160 and top mirror structure 162 comprising, for example, 3 or 4 periods of alternating materials, one such material being a high-Al material suitable for lateral oxidation. The epitaxial regrowth may preferably be accomplished by organo-metallic vapor phase epitaxy (OMVPE), for example at a temperature of greater than 700°C, and may take on the order of 1-2 hours. Alternatively the top mirror may be deposited after the semiconductor processing and may comprise, for example, dielectric layers. In a preferred implementation, the annealing/interdiffusion step of Figure 6B may be accomplished simultaneous with the regrowth step of Figure 6C in the epitaxial reactor, perhaps by modifying the temperature and time exposure.

Figure 6D illustrates isolation implant 94, masked by photoresist 166 and used to isolate the device shown from nearby other devices (not shown). The isolation implant is not always necessary, but is preferred when the etching to expose the AlAs layers does not surround the device.

Figure 6E illustrates an ohmic etch/deposition step in which holes 168 are etched through regions defined by masks 170. Preferably, holes 168 reaches down to regrown conductive spacer 160 and first ohmic contact 96 is then deposited with the mask still intact. An annealing step for first ohmic contact 96 may take place shortly after deposition or at some later time, perhaps after a second ohmic contact is deposited. Although not explicitly shown until Figure 6J, first ohmic contact 96 may preferably be in the form of a ring surrounding top mirror 162, and will thusly be referred to as a single contact even though two contact regions are identified in Figure 6E.

Figure 6F illustrates a second etch is performed masked by photoresist 172, forming larger holes 174 which reaches through oxidizing layers 24 and nonoxidizing layers 26. First ohmic contact 96 may serve as a mask to prevent etching of the region below first ohmic contact 96.

Figure 6G illustrates the result of the oxidation step forming oxidized layers 175 and oxidized mirror layers 176, showing that the oxidation proceeds throughout the top mirror layers and only to oxidation barrier 32 through oxidizing layers 24. Oxidation is performed as described in the art, for example at 425°C in a water vapor rich atmosphere for 1-4 hours.

Figure 6H illustrates the deposition of interconnect metal 100 onto first ohmic contact 96 and masked by photoresist mask 177. Interconnect metal 100 is typically used for connecting devices to wirebond pads.

Figure 6I illustrates the formation of second ohmic contact 178 on the bottom of substrate 82. When a plurality of such devices are formed, second ohmic contact 178 may serve as a common contact for the plurality of devices.

Figure 6J illustrates a top view of the completed device, showing exemplary patterning of first ohmic contact 96, interconnect metal 100, oxidation barrier 32 and larger hole 174.

Referring now to Figure 7, there is shown vertical cavity light emitter 180 in accordance with the present invention which is formed on substrate 182 which does not comprise GaAs. Exemplary materials for substrate 182 include GaP, GaAs, InP, InAs, GaSb or InSb. Since it has proven difficult and impractical to grow effective mirrors on non-GaAs substrates, oxidized mirror 184 may be employed to fabricate practical light emitters including VCSELs on non-GaAs substrates. Oxidized mirror 184 comprises oxidized layers 186 and nonoxidized layers 188. Oxidized layers 186 are typically oxidized from materials originally primarily comprising Al as the group-III element, for example AlP, AlAsP, AlGaAsP, AlAsP, InAlAs, InAlGaAs, AlAsSb, AlAsSbP, AlGaAsSb, or InGaAl AsSbP. Typically, Al will comprise at least 60% of the group-III material in oxidized layers 186. Light emitter 180 furthermore comprises first spacer 190, active material 192, second spacer 194, and top mirror 196. Top mirror 196 may be an oxidized mirror or a dielectric mirror, in either case typically

comprising high-index layers 198 and low-index layers 200. Alternatively, top mirror 196 may comprise a metal or a combination of metal with high-index and/or low-index layers. Exemplary materials comprising a dielectric top mirror are Si/SiO₂, which have a very large difference between their refractive indices. Light emitter 180 typically also comprises first ohmic contact 96 and second ohmic contact 128, and may optionally comprise current confinement means 204. Current confinement means 204 may comprise, for example, ion implanted regions or oxidized layers. An exemplary light emitter 180 is a VCSEL comprising an InP substrate, AlAsSb or AlGaAsSb (high-Al) oxidized layers, and InGaAs quantum well active material, which emits light in the 1.25-1.6 μm wavelength region.

Referring now to Figure 8, there are shown means for accomplishing precise wavelength control through the present inventive means. Due to the much lower refractive index of aluminum oxide compared to AlAs (about 1.6 compared to 3.0) the presence of the oxidized layers produce a shift toward shorter wavelengths in the VCSEL spectrum. If the current aperture formed by the oxidized layers is small, such as is desired for single-transverse-mode emission, then the wavelength of the fundamental transverse mode in a VCSEL will also be blue-shifted. The smaller the aperture, the larger will be the shift. It is thus possible to use this effect to provide precise control of emission wavelengths on a VCSEL wafer. Precise wavelength control is desired, for example, in VCSELs used for spectroscopic sensing of gases such as oxygen or cesium. One problem encountered in manufacturing VCSELs for spectroscopic sensing is nonuniformity of epitaxial layer thicknesses across the wafer. Nonuniform layer thickness produce nonuniform emission wavelengths across the wafer, typically with shorter wavelengths near the edge of the wafer.

Figure 8A illustrates wavelength-controlled wafer 206 and shows how laterally controlled oxidation may be used to produce uniform wavelengths in spite of nonuniform thickness across the wafer. The example of Figure 8A is for a wafer 206 which is thickest in the center. Normally such a wafer would emit longer wavelengths near the wafer center. By varying the diameters of the oxide-produced current

apertures with smaller apertures near the center, the VCSELs near the center have larger blue-shifts which compensate for their otherwise longer wavelengths. The circles in Figures 8A, 8B and 8C are qualitative and schematic representations of the current aperture sizes and are not drawn to scale with respect to the wafer or to each other. Thus a VCSEL (or LED) aperture 208 in a central region may be formed smaller than aperture 210 in an edge region such that both devices may emit at the same or nearly the same wavelength. Figure 8B illustrates wavelength-adjusted wafer 212 and shows how aperture control can also compensate for thickness variations from one wafer to another. The aperture pattern of Figure 8B, like that of Figure 8A, produces uniform wavelength emission over a wafer of nonuniform thickness, for example aperture 208' in the central region are smaller than apertures 210' in edge region. However, all the apertures in Figure 8B are smaller than the corresponding apertures of Figure 8A, for example aperture 208' near center of wafer 212 may be smaller than corresponding aperture 208 near center of wafer 206. Thus if the wafer of Figure 8B had a similar thickness distribution as that of Figure 8B, but was overall thicker, both wafers may emit the same wavelengths.

Figure 8C illustrates multiple-wavelength chip 214 comprising light emitters having different size oxidized apertures which cause them to emit at different wavelengths. Emitter 216 has a larger aperture and therefore emits at a longer wavelength than emitter 218. Emitter 220 has an aperture size and emission wavelength intermediate between those of emitter 216 and emitter 218. Chip 214 may furthermore include emitter 216' having characteristics nominally identical to emitter 216. One application for such an array is fiber communication using wavelength division multiplexing. The sizes of the apertures for multiple-wavelength arrays may also be scaled over the wafer in a similar manner as is shown in Figures 8A to produce nearly identical wavelength distributions over an entire wafer. and 8B. The apertures may also be scaled from one mask to another to compensate for wafer-to-wafer variations in thickness as was described for Figures 8A and 8B.

Referring now to Figure 9 there is shown structure 222 comprising active region 224, first spacer 225 first portion 226, second portion 228, and second spacer 230. Structure 222 is exemplary of portions of a VCSEL or other structures which are most pertinent to the present invention. To form a conductive element, first portion 226 is intended to be oxidized, second portion 228 is intended to be conductive and to become an oxidation barrier, and active region 224 is intended to be preserved as much as possible. In discussing the issues involved in processing structure 222, for simplicity, the IEI process is described, but an IILD process would proceed very similarly. Preferably, the implantation would produce maximum effect in second portion 228, while producing negligible effect in active region 224 or first portion 226. The interdiffusion of oxidizing and nonoxidizing layers (present but not shown) renders second portion 228 resistant to the oxidation process. Importantly, it is not necessary to achieve complete interdiffusion for lateral control of oxidation. For example, if the oxidizing and nonoxidizing layers comprise equal thickness layers of AlAs and AlGaAs with $x=0.4$, complete interdiffusion would produce AlGaAs with $x=0.7$. Only about 13% interdiffusion is required to reduce the oxidation rate in the interdiffused region by an order of magnitude compared to the AlAs layers. 43% interdiffusion would produce a two-orders-of-magnitude reduction. Thus a partial interdiffusion may be preferred over complete interdiffusion since it may be sufficient to form an oxidation barrier while preserving the integrity of the active region as much as possible. An interdiffusion of 50% or less distinguishes the present invention from the prior art even for the case of a non-electrically-conductive lateral oxidation barrier.

Another way to preserve the active region is to use an annular oxidation barrier as shown in Figure 1C. Masking of the implantation in the center of the VCSEL cavity protects most of the active region. The interdiffused region therefore forms a "moat" around the VCSEL cavity which prevents the oxidation from reaching inside the VCSEL cavity.

Another technique may be used to minimize the dosage of implantation required to produce sufficient interdiffusion to form an oxidation barrier. Referring

to Figure 1B, use of compressive strain in nonoxidizing layer 26 and/or use of tensile strain in oxidizing layer 24 will promote the transfer of non-Al materials from nonoxidizing layer 26 to oxidizing layer 24. Compressive strain may be created, for example, by incorporating In into GaAs layers, forming InGaAs. Similarly, tensile strain may be created, for example, by incorporating P into AlAs layers, forming AlAsP. It is understood in the art that significant compressive or tensile strain may be provided by incorporation of non-lattice matching materials, for example InAs in GaAs to form InGaAs, in which the non-lattice matching material has a concentration of about 1% or more. The combination of tensile strain and compressive strain in a superlattice of oxidizing layers 24 and nonoxidizing layers 26 allows the strain to be increased without causing dislocations and allows thicknesses to be increased. The presence of P is not expected to affect the oxidation process severely since InAlGaP/InGaP heterostructures have been successfully oxidized as reported by F.A. Kish et al. in the publication entitled "Native-Oxide Stripe-Geometry In(AlGa)P-InGaP Heterostructure Laser Diodes," which appeared in Applied Physics Letters, volume 59, pp. 354-356, 1991. The use of compressive and/or tensile strain may be used in any of the other material systems as well.

Various ion species may be used in the implantation. Ga and As ions are natural choices since they are the main constituent species of AlGaAs semiconductor structures. Ga has the additional advantage of being the element introduced into the AlAs layers to suppress oxidation, although the concentration of Ga introduced by implantation is negligible. If the oxidation barrier is within n-doped material, implantation with Si will enhance the conductivity, since the expected dosage will produce a Si concentration comparable with that of the n-type dopant (e.g. Si). In fact, use of Si or Te implantation into a region on the n-side of a p-n junction may eliminate the need for significant doping during growth of the oxidizing layer. If the oxidation barrier is within p-doped material, use of Si may reduce the conductivity unacceptably. In this case an implantation species should be used which is also a p-dopant, e.g. C, Be, Zn, N or Mg. Again use of these implantation species may eliminate the need for significant doping during growth of the superlattice. Since

doping also promotes interdiffusion, it is desirable to minimize doping in order to minimize interdiffusion in regions where oxidation is intended. It is therefore possible to create a conductive element of the present invention in which the initial, i.e. grown-in before implantation or diffusion, average impurity concentration is less than 10^{17} cm⁻³.

Referring again to Figure 1B, the most desirable composition of nonoxidizing layer 26 is determined by many factors. A zero-order analysis would choose a material containing no Al. However, the more complex issues that arise in an actual device may dictate or prefer other choices. If the device is to be a light emitter such as a VCSEL, the oxidation barrier must be transparent, or nearly so, to the emission wavelength. Thus, for examples, AlGaAs an Al concentration of $\geq 10\%$ is desired for 850 nm emitters, and Al concentrations $\geq 40\%$ are desired for 650 nm emitters. For oxidation barriers in a p-doped region, electrical conductivity presents another issue. If only a small degree of interdiffusion is sought, e.g. 25%, then large differences in Al composition may cause large electrical resistance (as is well known from VCSEL p-doped mirrors). Thus, even for longer-wavelength emitters such as 850 nm it may sometimes be desirable to have Al concentrations $\geq 40\%$ in the nonoxidizing layers.

When standing wave light emitters are formed such as VCSELs or resonant cavity LEDs, it may furthermore be advantageous to place oxidation barriers 32 at or near a node of the standing wave in order to minimize the absorption effects due to impurities introduced in formation of oxidation barrier 32. Maximum advantage is obtained when the thickness of oxidation barrier is less than three eighths of an optical wavelength in the optical material. The technique of placing absorptive material in standing wave nodes is discussed in the publication by Jewell, *et al.*, entitled "Surface-Emitting Lasers Break the Resistance Barrier," which appeared in *Photonics Spectra*, vol. 27, pp. 126-130. 1992.

It is to be appreciated and understood that the specific embodiments of the invention are merely illustrative of the general principles of the invention. Various

modifications may be made upon the preferred embodiments described consistent with the principles set forth. The scope of the invention is indicated by the appended claims rather than by the foregoing description.

WHAT IS CLAIMED IS:

1. An electrical current conducting element comprising:
 - at least a first oxidizing layer;
 - said first oxidizing layer being significantly oxidized in a laterally oriented first region, said first region exhibiting high electrical resistance;
 - said first oxidizing layer being modified within a laterally oriented second region forming a lateral oxidation barrier, said lateral oxidation barrier defining said second region which is not significantly oxidized and having electrical resistance significantly lower than said first region.
2. The conducting element recited in claim 1, further comprising a least one nonoxidizing layer adjacent to said oxidizing layer, and in which said modification of said first oxidizing layer comprises interdiffusion of said first oxidizing layer with said at least one nonoxidizing layer.
3. The conducting element recited in claim 1 wherein said second region is surrounded by said first region, forming an aperture.
4. The conducting element recited in claim 1 wherein said at least one oxidizing layer comprises a single oxidizing layer.
5. The conducting element recited in claim 1 wherein said at least one oxidizing layer comprises a plurality of oxidizing layers.

6. The conducting element recited in claim 2 wherein said at least one oxidizing layer is less than 500 angstroms thick.
7. The conducting element recited in claim 2 wherein said at least one oxidizing layer and said at least one nonoxidizing layer, both in said first region, have an average impurity concentration of less than 10^{17} cm^{-3} .
8. The conducting element recited in claim 2 wherein said interdiffusion has been enhanced by an ionic species.
9. The conducting element recited in claim 8 wherein said conducting element is further characterized being a first conductive type and wherein said ionic species is a dopant of said first conductive type.
10. The conducting element recited in claim 9 wherein said conducting element is p-type conductive and wherein said ionic species comprises an ionic species from the group including: carbon, zinc, beryllium, nitrogen or magnesium.
11. The conducting element recited in claim 9 wherein said conducting element is n-type conductive and wherein said ionic species comprises an ionic species from the group including: silicon or tellurium.

12. The conducting element recited in claim 2 wherein said at least one oxidizing layer is further characterized by tensile strain provided by a non-lattice-matching material having a concentration of at least 1 percent.
13. The conducting element recited in claim 2 wherein said at least one nonoxidizing layer is further characterized by compressive strain provided by a non-lattice-matching material having a concentration of at least 1 percent.
14. The conducting element recited in claim 2 wherein said interdiffusion is less than 100%.
15. The conducting element recited in claim 2 wherein said interdiffusion is less than 50%.
16. The conducting element recited in claim 2 wherein said interdiffusion is provided by ion enhanced interdiffusion.
17. The conducting element recited in claim 2 wherein said interdiffusion is provided by impurity induced layer disordering.
18. The conducting element recited in claim 2 wherein said interdiffusion is provided by optically induced local heating.

19. The conducting element recited in claim 2 in which at least one of said nonoxidizing layers resides above said first oxidizing layer and which further comprises at least one etched sidewall extending through said at least one of said nonoxidizing layers and into said first oxidizing layer;
said sidewall surrounding said lateral oxidation barrier.

20. The conducting element recited in claim 2 in which at least one of said nonoxidizing layers resides above said first oxidizing layer and which further comprises at least one etched sidewall extending through said at least one of said nonoxidizing layers and into said first oxidizing layer;
said sidewall not surrounding said lateral oxidation barrier.

21. The conducting element recited in claim 1 which comprises a plurality of said conducting elements.

22. The conducting element recited in claim 21 further comprising isolation means for providing electrical isolation between at least two elements of said plurality of conducting elements.

23. The conducting element recited in claim 22 wherein said isolation means comprises an ion implantation.

24. The conducting element recited in claim 1 wherein said conducting element is further characterized being a first conductive type;

said conducting element further comprising material of a second conductive type residing above or below said conducting element;

said conducting element and said material of a second conductive type forming an electrical junction.

25. The conducting element recited in claim 24 further comprising a light emitting material situated between said conducting element and said material of a second conductive type, forming a light emitting element.

26. The light emitting element recited in claim 25 wherein said light emitting element comprises a light emitting diode.

27. The light emitting element recited in claim 25 wherein said light emitting element comprises an edge-emitting laser diode.

28. The light emitting element recited in claim 25 wherein said light emitting element further comprises:

a substrate;

a first mirror situated above said substrate;

a first conductive spacer situated above said first mirror and below said light emitting material;

a second conductive spacer situated above said light emitting material;

a second mirror situated above said second conductive spacer;

a first contact for electrically contacting to said conducting element,
and;

a second contact for electrically contacting to said material of a second
conductive type;

said first and second mirrors and all material between forming an
optical cavity having a cavity resonance at a nominal wavelength;

means for injecting electrical current through said conducting element
and into said light emitting material, thereby causing said light emitting device
to emit a beam of light at or near said nominal wavelength.

29. The light emitting element recited in claim 28 wherein said conductive element resides above said light emitting material.
30. The light emitting element recited in claim 28 wherein said first mirror comprises semiconductor layers.
31. The light emitting element recited in claim 28 wherein said first mirror comprises alternating layers of semiconductor and oxidized layers.
32. The light emitting element recited in claim 28 wherein said second mirror comprises semiconductor layers.
33. The light emitting element recited in claim 28 wherein said second mirror comprises alternating layers of semiconductor and oxidized layers.

- ✓
34. The light emitting element recited in claim 28 wherein said second mirror comprises dielectric layers.
- ✓
35. The light emitting element recited in claim 28 wherein said second region is surrounded by said first region, thereby forming an aperture.
- ✓
36. The light emitting element recited in claim 35 wherein said light emitting element comprises a plurality of light emitting devices, at least two of said apertures on at least two of said light emitting devices having different sizes.
- ✓
37. The light emitting element recited in claim 36 in which said plurality of light emitting devices are fabricated on a wafer, and in which said different sized apertures are predetermined to decrease the variation in said nominal wavelengths across said wafer.
- ✓
38. The light emitting element recited in claim 36 in which said plurality of light emitting devices comprise at least first and second light emitting devices which are fabricated on similar locations on at least first and second wafers, said similar locations on said wafers having different thicknesses of said optical cavities;

in which said different aperture sizes are predetermined to decrease the difference between said nominal wavelengths of said first and second light emitting devices.

39. The light emitting element recited in claim 36 in which said plurality of light emitting devices are fabricated on a chip, and in which said different aperture sizes are predetermined to increase the variation in said nominal wavelengths across said chip.

40. An electrical current conducting element comprising:

at least a first oxidizing layer directly adjacent to and above or below
at least one nonoxidizing layer;

said first oxidizing layer being significantly oxidized in a first region,
said first region exhibiting high electrical resistance;

said first oxidizing layer and said at least one nonoxidizing layer being
at least partially interdiffused within a second region forming a composite
layer, said composite layer being not significantly oxidized, said second region
having electrical resistance significantly lower than said first region.

41. The conducting element recited in claim 40 in which said oxidizing layer comprises oxidized portions and interdiffused portions of an initial material, in which the aluminum content of said initial material is greater than that of said nonoxidizing layer, and in which said nonoxidizing layer and said initial material respectively comprising material pairs selected from the group consisting essentially of: GaAs/AlAs, AlGaAs/AlGaAs, InAlGaAs/AlGaAs, InAlGaAs/AlGaAsP, InAlGaP/AlGaAs, InAlGaP/AlGaAsP, GaAsSb/AlAsSb,

AlGaAsSb/AlGaAsSb, GaPSb/AlPSb, AlGaPSb/AlGaPSb, InGaAs/AlGaAsSb,
and InGaAsP/AlGaAsSb.

42. A vertical cavity surface emitting laser comprising:

a substrate;

a first mirror situated above said substrate;

a first conductive spacer situated above said first mirror;

a light emitting material;

a second conductive spacer situated above said light emitting material;

a second mirror situated above said second conductive spacer;

at least a first oxidizing layer, said first oxidizing layer being
significantly oxidized in a laterally oriented first region, said first region
exhibiting high electrical resistance, said first oxidizing layer being modified
within a laterally oriented second region forming a lateral oxidation barrier,
said lateral oxidation barrier defining said second region which is not
significantly oxidized and having electrical resistance significantly lower than
said first region;

a first contact for electrically contacting to said conducting element;

a second contact for electrically contacting to said material of a second
conductive type;

said first and second mirrors and all material between forming an
optical cavity having a cavity resonance at a nominal wavelength; and

means for injecting electrical current through said conducting element and into said light emitting material, thereby causing said light emitting device to emit a beam of light at or near said nominal wavelength.

43. The laser recited in claim 42 in which said nominal wavelength is greater than 1.2 μm .

44. A light emitter comprising:

a first mirror;

a light emitting material;

a second mirror;

at least a first oxidizing layer, said first oxidizing layer being significantly oxidized in a laterally oriented first region, said first region exhibiting high electrical resistance, said first oxidizing layer being modified within a laterally oriented second region forming a lateral oxidation barrier, said lateral oxidation barrier defining said second region which is not significantly oxidized and having electrical resistance significantly lower than said first region.

45. The light emitter recited in claim 44 further comprising an InP substrate.

46. The light emitter recited in claim 44 in which said light emitter is a vertical cavity surface emitting laser.

47. The light emitter recited in claim 44 in which said light emitting material comprises InGaAs.
48. The light emitter recited in claim 44 further comprising a nonoxidizing layer, said oxidizing layer and said nonoxidizing layer being interdiffused in said second region, in which said oxidizing layer comprises oxidized portions and interdiffused portions of an initial material, said nonoxidizing layer and said initial material respectively comprising material pairs selected from the group consisting essentially of: GaAsSb/AlAsSb, AlGaAsSb/AlGaAsSb, InGaAs/AlGaAsSb, and InGaAsP/AlGaAsSb.
49. A vertical cavity surface emitting laser comprising:
- a substrate;
 - a first mirror situated above said substrate;
 - a first conductive spacer situated above said first mirror;
 - a light emitting material;
 - a second conductive spacer situated above said light emitting material;
 - a second mirror situated above said second conductive spacer;
 - means for electrically contacting to said first conductive spacer; and
 - means for electrically contacting to said second conductive spacer;
- said substrate comprising a material selected from the group consisting essentially of: GaP, InP, InAs, GaSb, and InSb; and
- said first mirror comprising high index layers and low index layers, at least one of said low index layers comprising an oxidized material.

50. The laser recited in claim 49 in which said oxidized material comprises an oxidized material originally selected from the group consisting essentially of: AlP, AlGaP, AlAsSb, AlGaAsSb, AlSb, AlPSb, AlGaPSb and InAlGaAsSb.

51. A method for producing an electrical conducting element comprising the steps of:

epitaxially growing at least a first oxidizing layer;

forming protection means in at least a first laterally oriented first region of said oxidizing layer, said protection means being to protect said oxidizing layer from modification;

modifying said oxidizing layer in at least a first laterally oriented second region not protected by said protection means, such modification inhibiting oxidation processes; and

oxidizing said oxidation layer in said first region, said modification inhibiting the oxidizing process in said second region.

52. The method recited in claim 51 further comprising the step of epitaxially growing at least a first nonoxidizing layer wherein said modifying said oxidizing layer comprises interdiffusion of said oxidizing layer with said nonoxidizing layer.

53. The method recited in claim 52 wherein said modifying said oxidizing layer further comprises an annealing process.

54. The method recited in claim 51 further comprising the step of epitaxial regrowth.
55. The method recited in claim 53 further comprising the step of epitaxial regrowth and wherein said modifying said oxidizing layer further comprises annealing in which said annealing step is at least partly provided during said epitaxial regrowth.
56. The light emitting element recited in claim 28, further comprising standing waves inside said cavity, wherein said oxidation barrier is located near a node of said standing waves.

ABSTRACT OF THE DISCLOSURE

5 A conductive element with a lateral oxidation barrier is provided for the control of lateral oxidation processes in semiconductor devices such as lasers, vertical cavity surface emitting lasers and light emitting diodes. The oxidation barrier is formed through modification of one or more layers which initially were receptive to oxidation. The quality of material directly below the oxidation barrier may be preserved. Related applications include the formation of vertical cavity surface emitting lasers on non-GaAs substrates and on GaAs substrates.

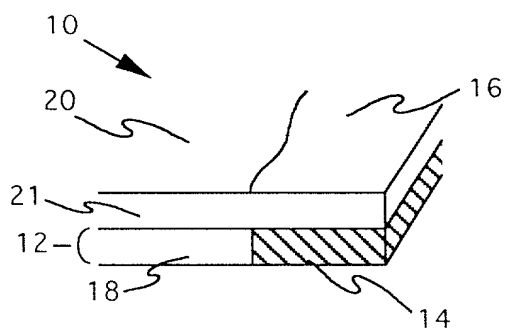


Figure 1A

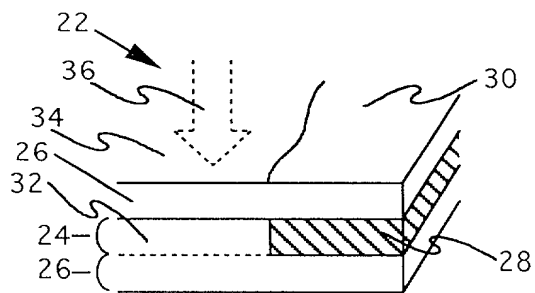


Figure 1B

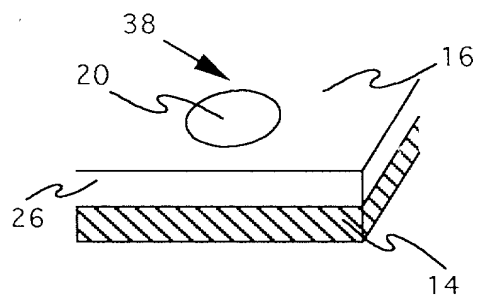


Figure 1C

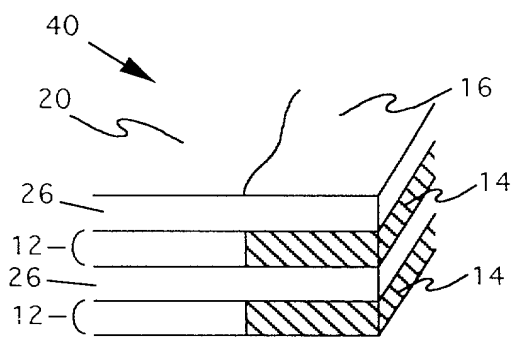


Figure 1D

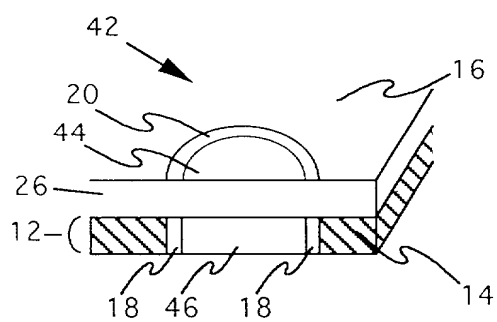


Figure 1E

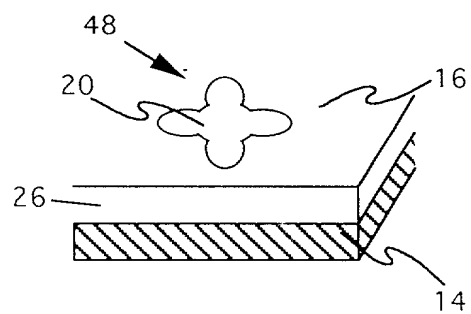


Figure 1F

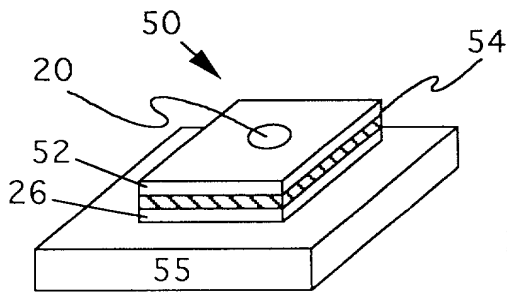


Figure 2A

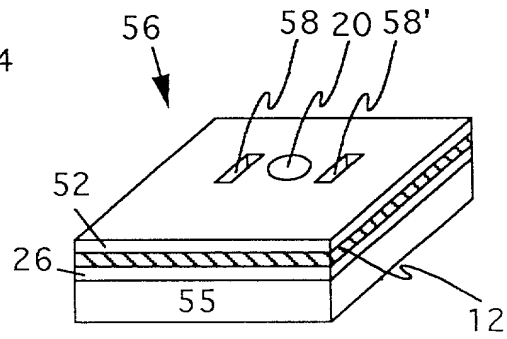


Figure 2B

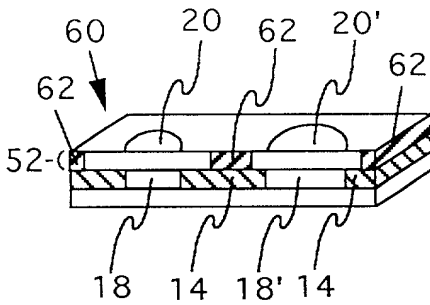


Figure 3

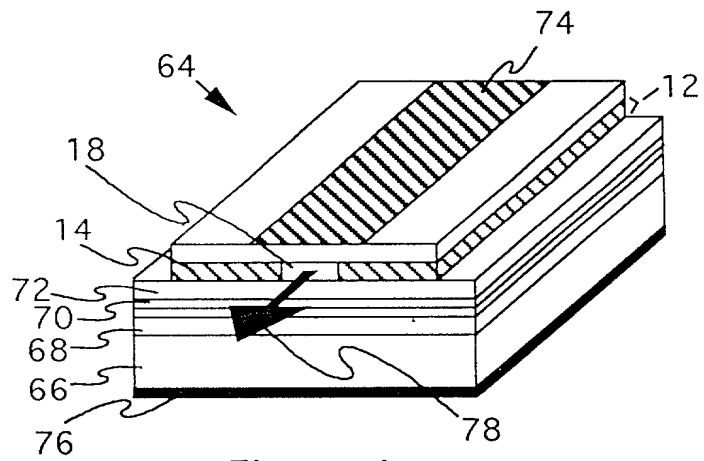


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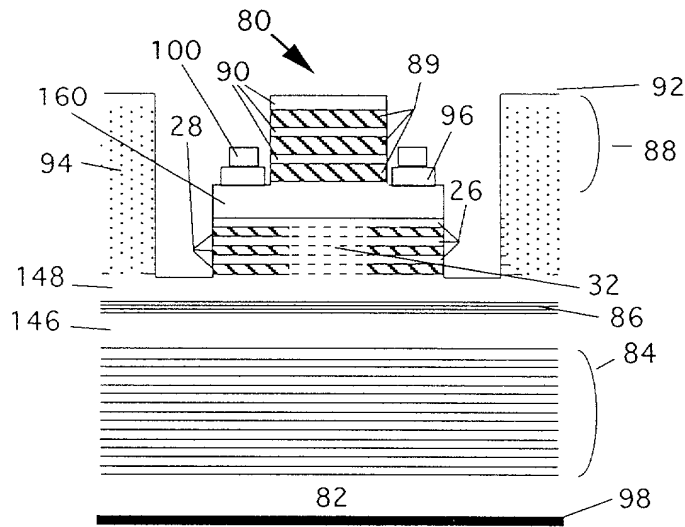


Figure 5A

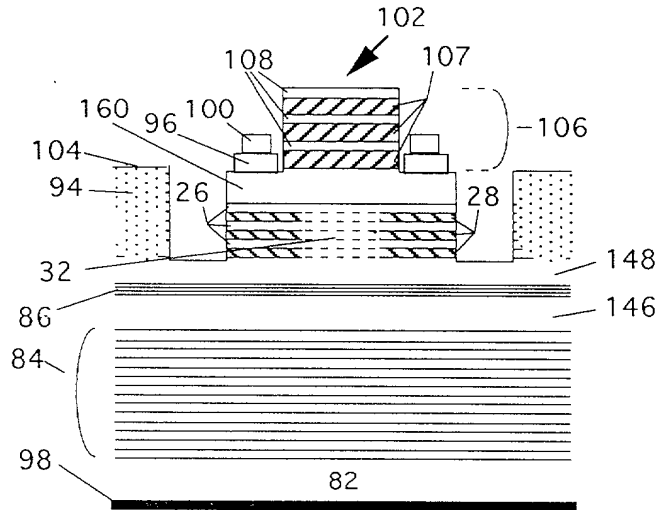


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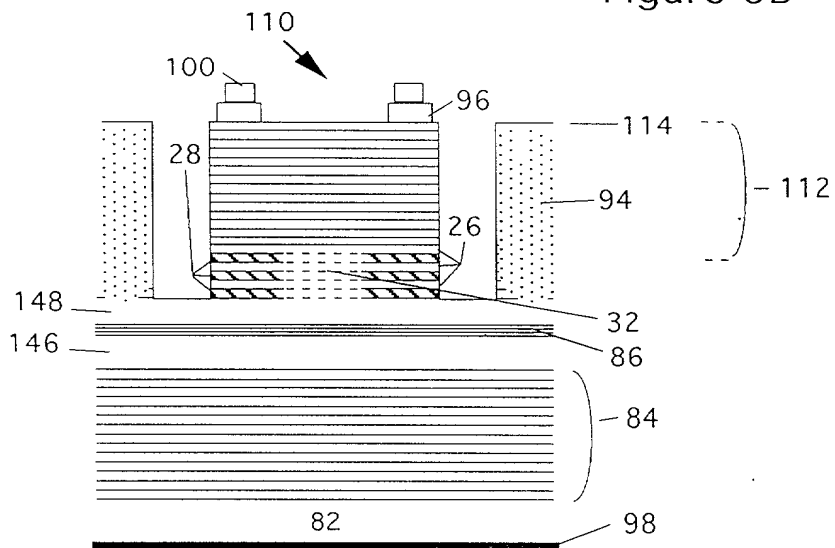


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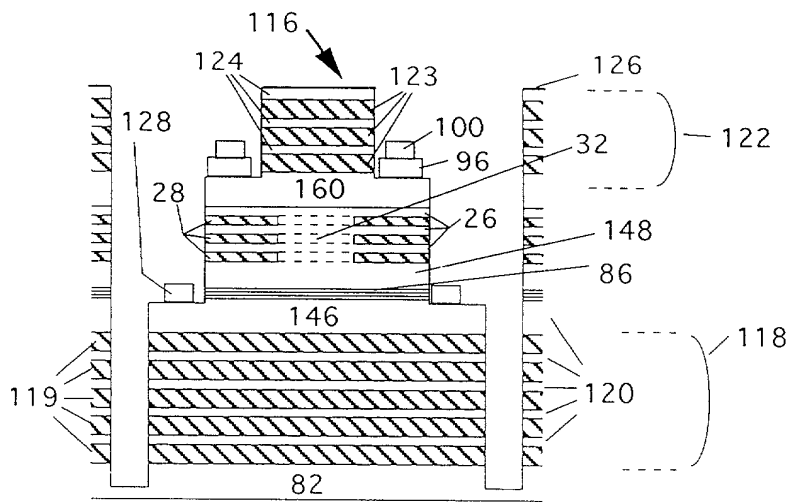


Figure 5D

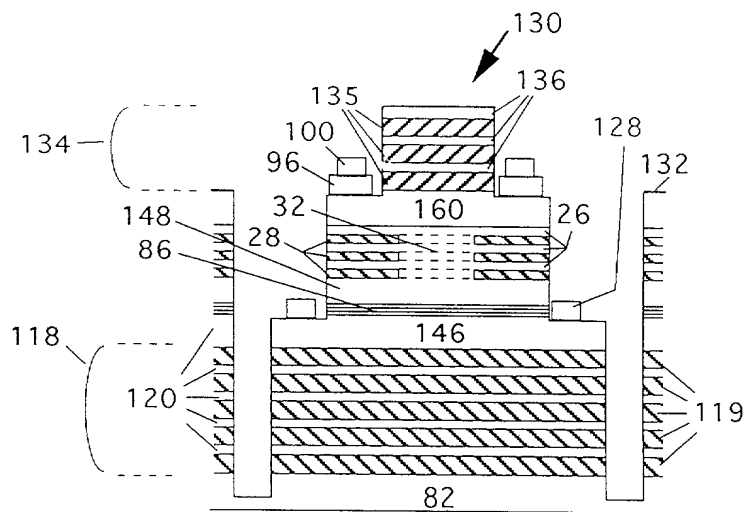


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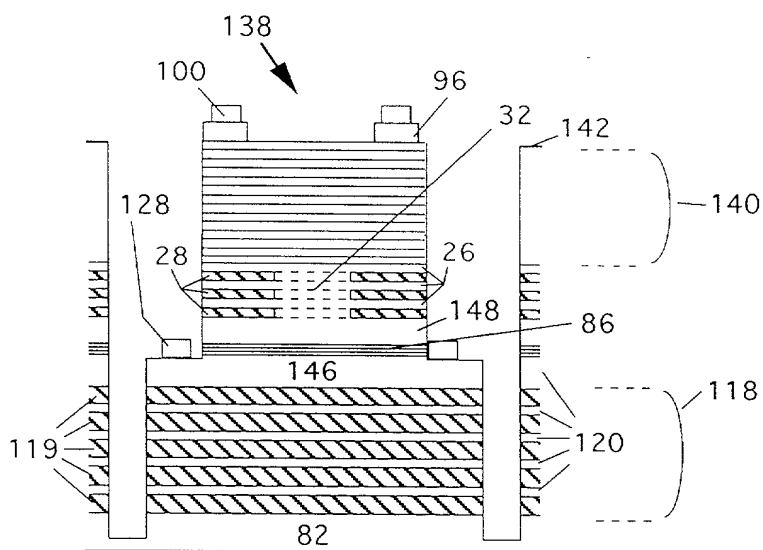


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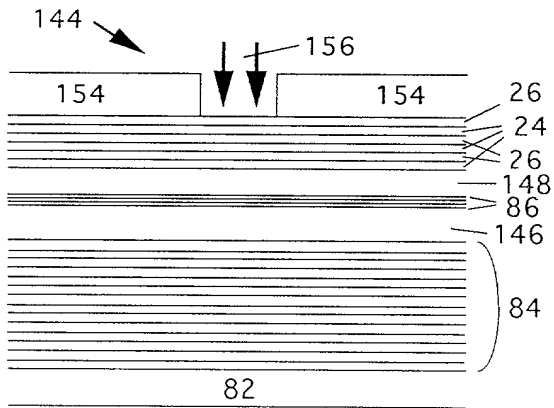


Figure 6A

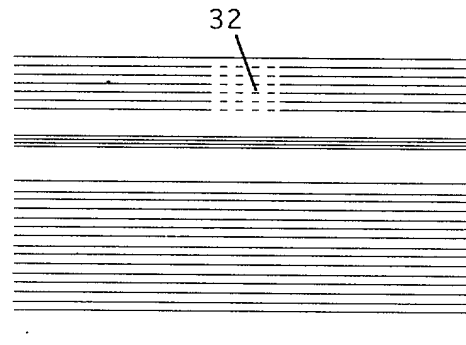


Figure 6B

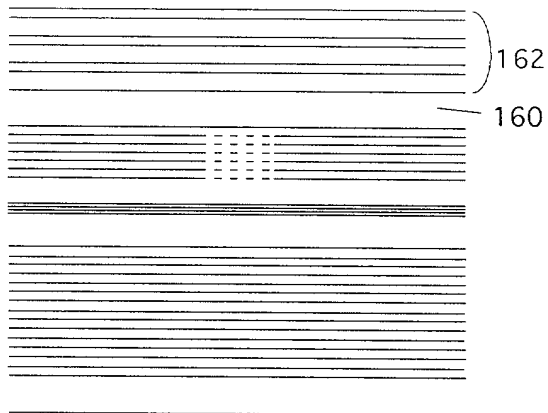


Figure 6C

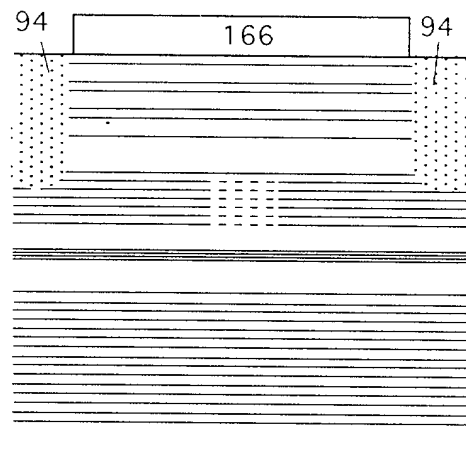


Figure 6D

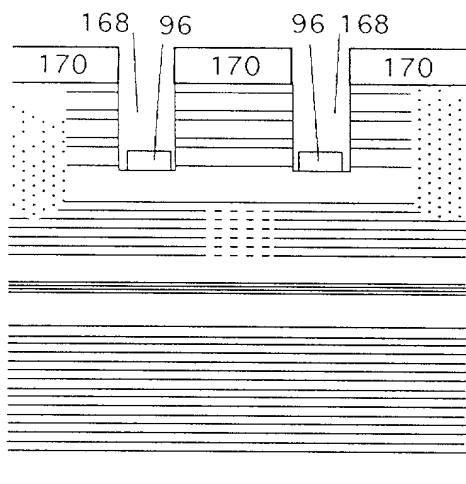


Figure 6E

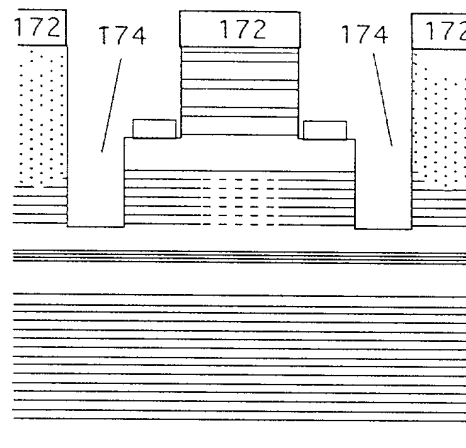


Figure 6F

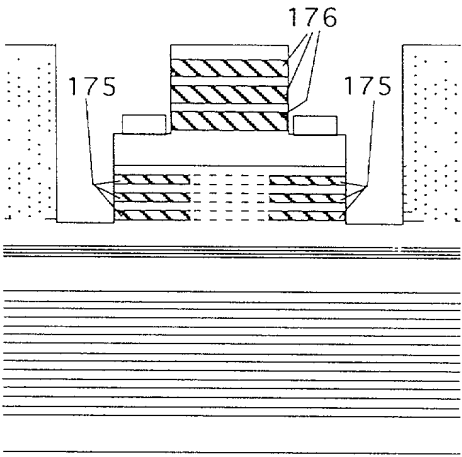


Figure 6G

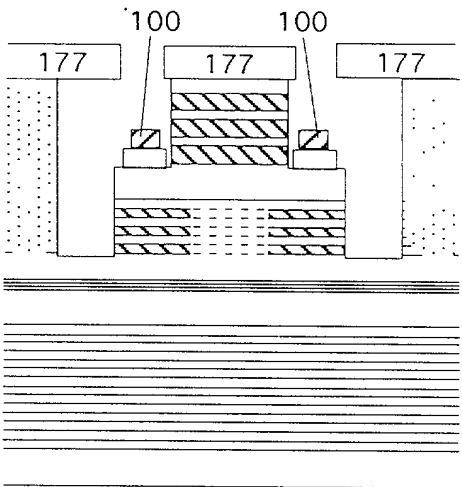


Figure 6H

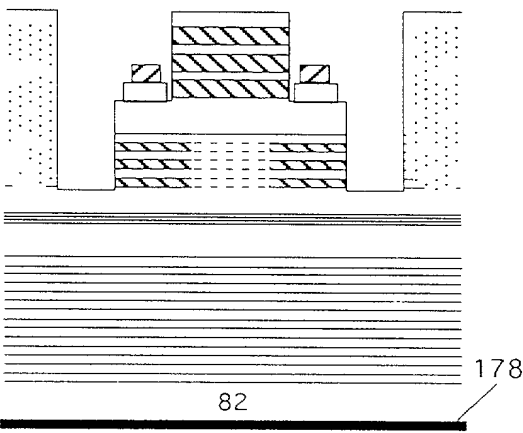


Figure 6I

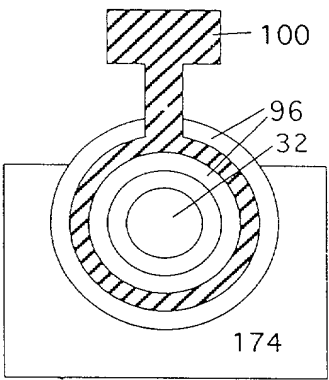


Figure 6J

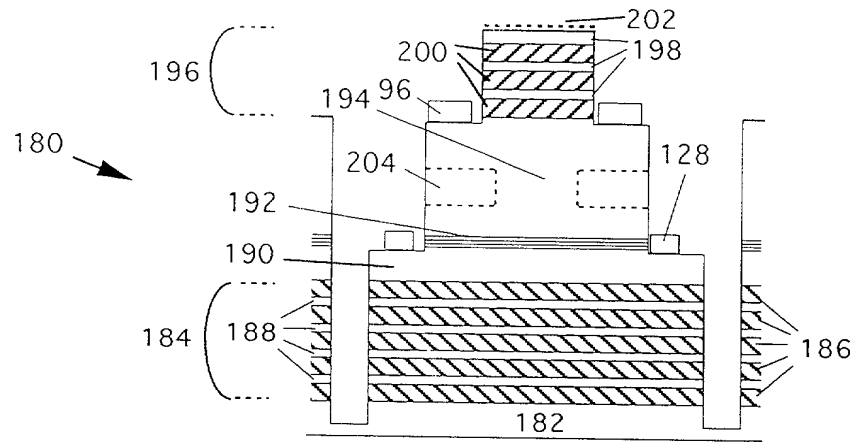


Figure 7

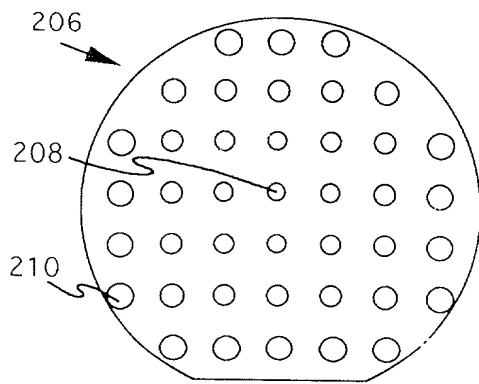


Figure 8A

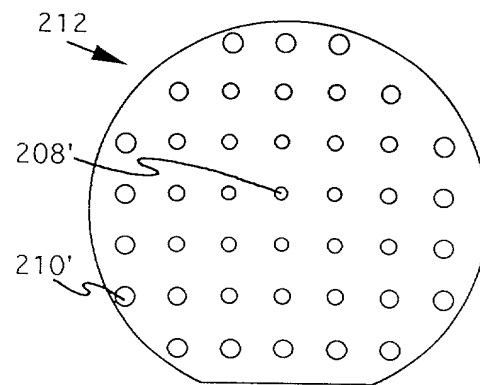


Figure 8B

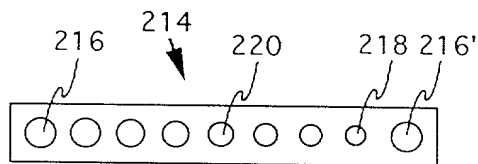


Figure 8C

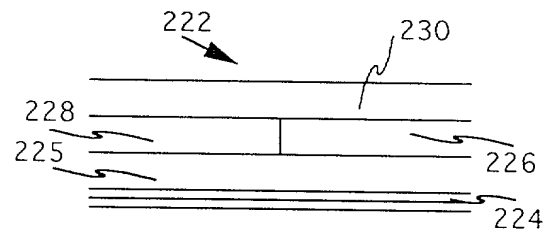


Figure 9

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FROM JAGTIANI AND ASSOC. 703 823 9387

P. 1

ATTORNEY DOCKET NO.: PRCO-0002

DECLARATION FOR PATENT APPLICATION AND APPOINTMENT OF ATTORNEY

As a below-named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention (Design, if applicable) entitled **CONDUCTIVE ELEMENT WITH LATERAL OXIDATION BARRIER**

the specification of which (check one):

☒ is attached hereto.☐ was filed on _____ as Application Serial No. _____, and was amended on _____ (if applicable).☐ was filed on _____ as International Application (PCT) No. _____, and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment(s) referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a). I hereby claim foreign priority benefits under Title 35, United States Code § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which the priority is claimed.

PRIOR FOREIGN APPLICATION(S)

| NUMBER | COUNTRY | DAY/MONTH/YEAR FILED | PRIORITY CLAIMED |
|--------|---------|----------------------|--|
| | | | <input type="checkbox"/> Yes <input type="checkbox"/> No |
| | | | <input type="checkbox"/> Yes <input type="checkbox"/> No |

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating The United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

| APPLICATION NUMBER | FILING DATE | STATUS (Patented, Pending or Abandoned) |
|--------------------|-------------|---|
| | | |
| | | |

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.


POWER OF ATTORNEY: I (We) hereby appoint as my (our) attorneys, with full powers of substitution and revocation, to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: **Ajay A. Jagtiani**, Registration Number 35,205.

Send correspondence to: **JAGTIANI & ASSOCIATES**
6126 Rocky Way Court
Centerville, Virginia 22020-3400

Telephone calls to:

(703) 855-5869

☐ See following pages for additional joint inventors.

| | |
|---|---|
| Full Name of First or Sole Inventor JEWELL, Jack L. | Citizenship United States |
| Residence Address - Street 4623 Sunshine Canyon Drive | Post Office Address Street 4623 Sunshine Canyon Drive |
| City Boulder | City Boulder |
| State or Country Colorado | State or Country Colorado |
| Zip 80342 | Zip 80342 |
| Date December 17, 1995 | Signature  |

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:)
JEWELL, Jack L..)
Serial Number: To be assigned) Art Unit: To be assigned
Filed: Concurrently Herewith) Examiner: To be assigned
For: CONDUCTIVE ELEMENT WITH LATERAL)
OXIDATION BARRIER)

Assistant Commissioner for Patents
Washington, D.C. 20231

ASSOCIATE POWER OF ATTORNEY

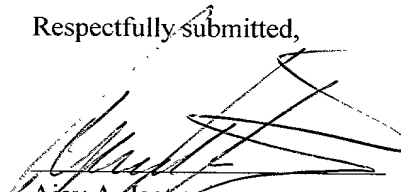
Sir:

I hereby appoint Mark Gutttag, Registration Number 33,057, as my associate attorney in the above-captioned application, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent Office connected therewith.

However, please continue to address all future communications to the undersigned attorney at the following:

Ajay A. Jagtiani
JAGTIANI & ASSOCIATES
10379-B Democracy Lane
Fairfax, Virginia 22030

Respectfully submitted,


Ajay A. Jagtiani
Registration Number 35,205

April 20, 2000

JAGTIANI & ASSOCIATES
Democracy Square Business Center
10379-B Democracy Lane
Fairfax, Virginia 22030

(703) 591-2664